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A HAND-BOOK

OF THE

ELECTRO-MAGNETIC TELEGRAPH

BY

A. E. LORING,
A PRACTICAL TELEGRAPHER

FOURTH EDITION REVISED.

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INTRODUCTION.

IT has been the aim of the author in the preparation of this little book, to present the principles of the Electro-Magnetic Telegraph, in a brief, concise manner, for the benefit of practical operators and students of telegraphy. The works on telegraphy which have thus far been presented, besides being expensive, have contained much that is useless, or which is not in a form to be readily understood by young and inexperienced telegraphers. Although this little work must be acknowledged incomplete, it is hoped that it may go far toward supplying the deficiency which has existed ; or, at least, serve as a stepping-stone to the study of the more complete works on electricity and telegraphy.

THE AUTHOR.

PREFACE TO FOURTH EDITION.

In the present edition, an attempt has been made to revise the original text, as the present state of telegraph practice requires, without increasing the size of the book. A new chapter, describing in outline the duplex and quadruplex methods of telegraphy has been added, however, which it is believed will materially increase the value of the work.

A. E. L.

January 5th, 1900.

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Part I.—Electricity and Magnetism.

Part II.—The Morse Telegraph.

Part III.—The Quadruplex.

Part IV.—Practical Telegraphy.

ELECTRO-MAGNETIC

TELEGRAPH.

ELECTRICITY AND MAGNETISM.

Electricity.—Positive and Negative.

The real nature of electricity is unknown. It is often spoken of as a *fluid*, and is said to *flow* in a *current*, but these terms may be considered as used more for the sake of convenience, than as indicating the real nature of electricity.

There are two kinds of electricity, or it exists in two different states, known as *positive* and *negative;* and experiment shows, that whenever one kind is developed that of the opposite kind is always developed in an exactly equal quantity. These two kinds of electricity are usually designated by the signs + and —. It is a law of electricity, that *electricities of like sign*

repel each other, and electricities of unlike sign attract each other.

Conductors and Non-Conductors.

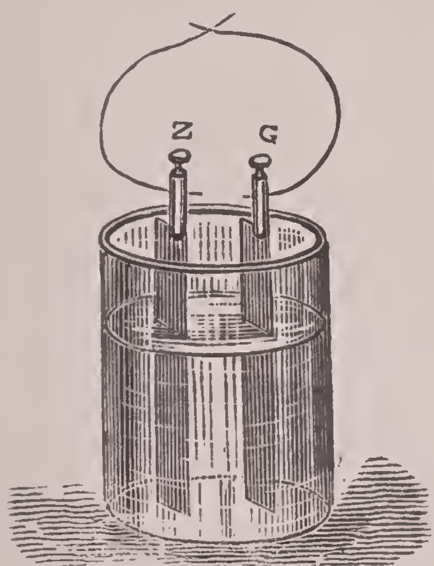
Electricity passes through some substances easily, and through others with difficulty, or scarcely at all. The first class of substances are called *conductors,* the second *non-conductors,* or *insulators.* No absolute division can be made between conductors and non-conductors, as the property of conduction exists in every conceivable degree, from the best conductor to the best insulator, or *worst conductor.* In the following list the first named substance is the best conductor, and the last named the best insulator.

Conductors.	Non-Conductors.
Silver,	Dry wood,
Copper,	Porcelain,
Gold,	Dry Paper,
Zinc,	Silk,
Platinum,	Glass,
Iron,	Gutta Percha,
Tin,	India Rubber,
Lead,	Shellac,
Mercury,	Hard Rubber
Acids,	Paraffine,
Water,	Dry Air.

Galvanic Batteries.

Galvanic, or Voltaic electricity is developed by chemical action. When two plates of metal, of different kinds, as copper and zinc, for example, are immersed in a cup containing an acid, and are con-

Fig. 1.



Galvanic Element.

nected by wires at the top, as represented in Fig. 1, a current of electricity will flow from the copper to the zinc through the wires, and from the zinc to the copper through the acid. If the wires connecting the two metals are separated, the cur-

rent of electricity instantly ceases, but starts again whenever the wires are connected. An apparatus for generating electricity in this way is called a *galvanic battery.* The copper slip is called the positive (+) *pole* of the battery, and the zinc the negative (—) pole. The principal kinds of batteries used in operating the telegraph will be described hereafter.

Galvanic Circuits.

The path traversed by the current of a battery is called a *circuit.* The circuit of the battery shown in Fig. 1 consists of the metals, wires, and the acid through which the current of electricity passes. It is a law of the electric current that *there must be a continuous, unbroken circuit, by which the current may pass entirely around from one pole of the battery to the other, or no current will start from the battery.* The smallest break in the circuit is sufficient to interrupt the current instantly, but it begins to flow again the instant the circuit is again completed. The direction of the current through the

circuit is always from the positive to the negative pole of the battery.

It may be more correct, however, considering the electrical force as a *current*, to say that there are two currents flowing in opposite directions, and for convenience the positive one only is spoken of as the current.

ELECTRICAL QUANTITY AND INTENSITY.

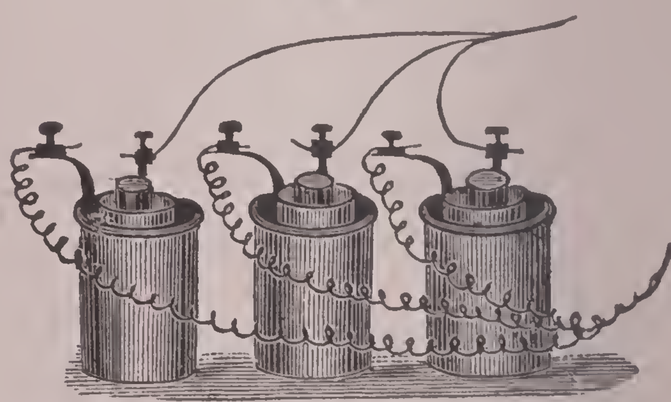
A battery may consist of a single cup, or cell, or of an indefinite number of cups connected together by wires. In connecting them together, the copper, or positive pole of the first cup must be connected by a wire with the negative pole of the second, and the positive pole of the second with the negative of the third, and so on throughout the series, always connecting unlike or opposite poles, because, according to the law of attraction and repulsion already stated, *poles of like sign oppose one another, and poles of unlike sign attract one another.*

The *quantity* of electricity generated by three cells of battery connected as

directed above, is no greater than that generated by one cell, but the *intensity* of the current generated will increase in proportion to the number of cells so connected. Intensity or *tension* is the force which enables the current to push its way through a conductor, or to overcome resistance.

If two or more cells of battery are connected as shown in Fig. 2, with all the

Fig. 2.



Galvanic Battery—Quantity Arrangement.

positive poles connected to one end of the wire conductor, and all the negative poles connected to the other end, the *quantity* of the current generated will be in proportion to the number of cells, but the

intensity of the current will be no greater than that of a single cell.

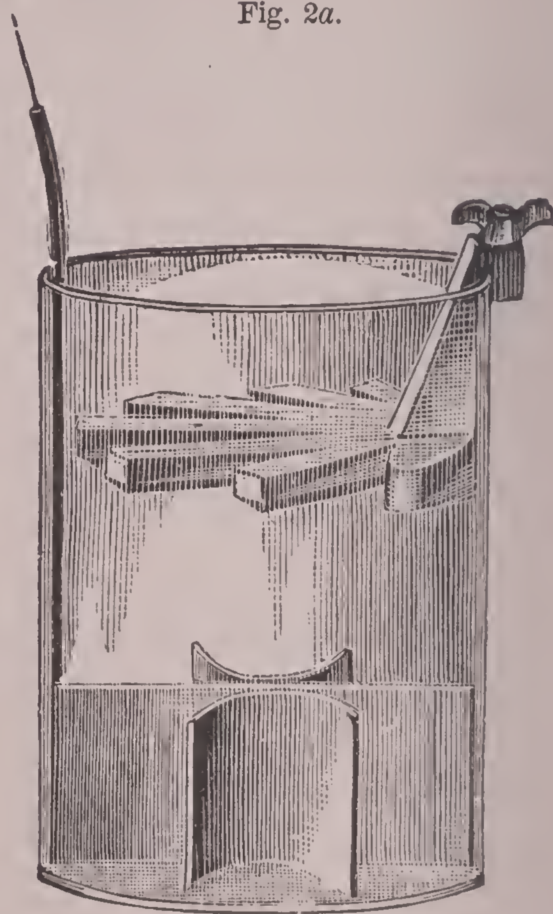
The general principle is, that quantity increases with the surface of metal connected with each pole, whether that surface is all in one cell, or distributed through several cells connected as in Fig. 2. The intensity increases with the number of elements, or cells, having opposite poles connected, and does not depend upon the size of the metals used. Consequently, large cells evolve a greater quantity of current than small ones, but of no greater tension.

Gravity Batteries.

The various forms of battery formerly used in operating the telegraph have been entirely superseded by the *gravity battery*. There are a variety of forms, without any material difference in the principle involved. That shown in Fig. 2*a* is the "crowfoot" battery, so called from the peculiar shape of the zinc. The copper is placed at the bottom of the jar, the zinc at the top. The sul-

phate of copper solution at the bottom of the jar and the sulphate of zinc solu-

Fig. 2*a*.



Gravity Battery.

tion at the top are kept separate by the difference in their specific gravities.

RESISTANCE.

Resistance is the opposition which the conductor, or circuit offers to the passage of the current. Thus the best conductor offers the least resistance, and the poorest conductor the greatest resistance. Resistance may be considered as the reciprocal of conduction. Resistance is measured by *Ohms*.

In the case of two conducting wires of the same material, that which presents the largest area of cross-section to the current offers the least resistance. Thus, although copper is a better conductor than iron, an iron wire of large size may have a lower resistance than a copper wire of smaller size. The conducting power of a wire increases, and its resistance decreases, in proportion as the area of its section increases. On the other hand, the resistance of a conducting wire of a given material increases in proportion to its length.

ELECTRO-MOTIVE FORCE.

The power which a cell of battery possesses of causing the transfer of its

current from one place to another is its *electro-motive force.* In other words, the elcctro-motive force of a current is its power of overcoming resistance—its energy. Electro-motive force may be defined as tension in a state of motion; and tension, as electro-motive force in a state of rest. (*Haskin's Galvanometer.*)

Electro-motive force, or potential, is measured by the unit called the *Volt.*

Ohm's Law.

The amount of the current which will pass through a circuit depends, first, upon the resistance which the circuit offers to the passage of the current, and second, upon the intensity of the electro-motive force which tends to overcome that resistance. The amount of the current may be found, according to *Ohm's law*, which may be stated thus:

E represents the electro-motive force,

R the resistance, and

C the current which will pass through the circuit, thus:

$$C = \frac{E}{R}$$

Fig. 3.

Galvanometer.

or, *the current is equal to the electro-motive force divided by the resistance.*

Measurement of Currents.

Electric currents may be measured by an instrument called a *galvanometer*, one form of which is shown in Fig. 3. It consists of a magnetic needle surrounded by a coil of insulated wire. When a current is passed through the coil of wire, its amount is marked by the deflection of the needle on the face of a dial, the degree of deflection being always in proportion to the strength of the current. The strength of the current is measured by a unit called the *ampere*.

Measurement of Resistance.

The resistance of a conductor may be measured by an instrument called a *rheostat* (Fig. 4), used in connection with a galvanometer. The rheostat consists essentially of resistance coils of fine German silver wire inclosed in a box. Binding posts are provided for placing it in circuit, and any desired number of the

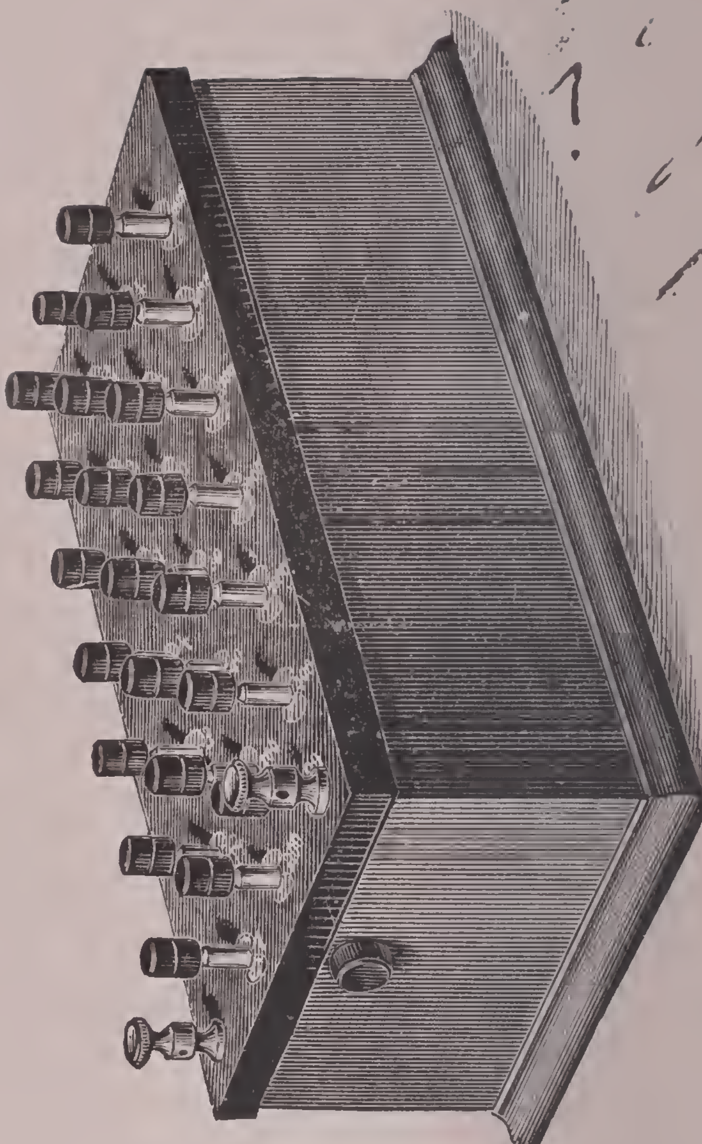
coils may be cut out by inserting brass plugs in the top of the box, according to the resistance required.

The rheostat and galvanometer are put in circuit with the conductor whose resistance is to be measured, and the deflection of the needle of the galvanometer is noted. The conductor to be measured is then taken out of the circuit, and as much resistance is thrown in by the rheostat as will give the same deflection of the needle. The resistance marked by the rheostat will, evidently, be equal to that of the conductor previously in circuit.

Divided Circuits.

When two or more wires are connected together so as to form one continuous wire, the resistance of the whole circuit will be the sum of the resistances of the wires which compose it. But if two or more wires are arranged side by side, the ends being connected with each other, the current is divided among the several conductors, and the conducting power

Fig. 4.



Rheostat.

of the whole is equal to the sum of the conducting power of the wires which compose it.

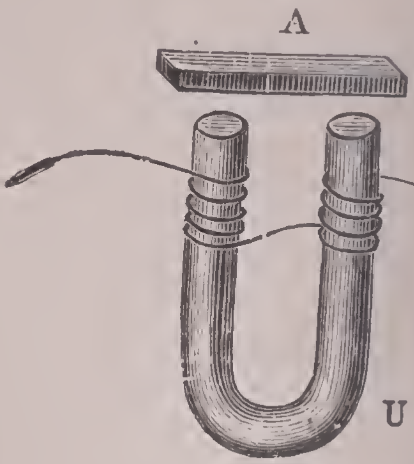
When a current of a given electro-motive force divides between two or more branches of the conductor, the strength of the current in each branch is, by Ohm's law, inversely proportional to the resistance. An important application of this principle occurs in the duplex and quadruplex systems of telegraphy, where the current is caused to divide equally between two branches of the conductor, —one consisting of the line and the other of a rheostat circuit adjusted to equal the resistance of the line.

Electro-Magnets.

A simple form of electro-magnet is shown in Fig. 5. A conducting wire, insulated by being covered with silk or cotton, so that the current must traverse its entire length, is wound several times around each arm of a U shaped piece of soft iron. When a current of electricity is passed through the insulated conduct-

ing wire, the soft iron U instantly becomes magnetized, and attracts an iron

Fig. 5.



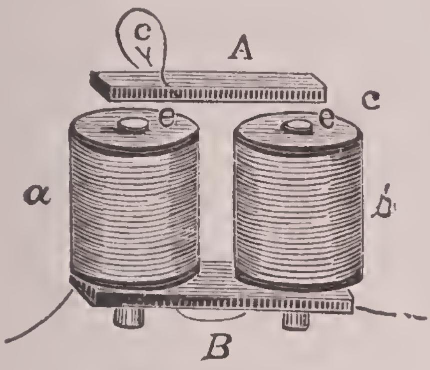
Simple Electro-Magnet.

bar, A, called an *armature*, which is placed near its ends or *poles*. As soon as the current of electricity ceases to pass through the wire, the soft iron U is demagnetized and ceases to attract its armature.

Electro-magnets for use in telegraphy are made as represented in Fig. 6. Two spools, *a b*, having soft iron cores, are wound with fine silk-insulated copper wire, as thread is wound upon a spool.

The two spools are fixed upon a bar of iron, B, called a *yoke*. A is the arma-

Fig. 6.



Electro-Magnet.

ture which is attracted toward the cores or poles, *e e*, whenever the current passes through the coils of the magnet.

Differential Magnets.

It will be observed that the wire passes around the soft iron U, Fig. 5, in such a direction that if the U is straightened out the convolutions will all lie in one direction. One end of the bar becomes the north pole and the other the south pole of the magnet, and the polarity may

be reversed by changing the direction of the current around the bar. This may be by either changing the direction of the coils, or by reversing the poles of the battery.

A differential electro-magnet may be made by passing two separate coils around the core, and its polarity is established according to the direction of the current. If currents of equal strength traverse the two coils in opposite directions they tend to establish opposite polarities and the magnetic effect is neutralized.

Magnetic Induction.

When either pole of a magnet is placed near any object capable of magnetization, it is attracted toward the magnet, the magnet pole nearest the object developing magnetism of the opposite polarity by induction, and the two mutually attract each other. Thus each pole of an electro-magnet develops magnetism of an opposite polarity, by induction, in that end of the armature nearest to it, and the armature is attracted toward the electro-magnet.

Residual Magnetism.

When the current which passes through the coils of an electro-magnet is interrupted, demagnetization of the soft iron cores takes place. If the iron is very soft and pure this is effected almost instantly on the cessation of the current through the coils. But if the demagnetization is not complete, and a small amount of magnetism remains in the cores after the cessation of the current, it is called *residual magnetism.* A spring is therefore attached to the armature of the magnet, which overcomes the attraction of the residual magnetism, and draws the armature away from the poles of the magnet.

Proportion of Electro-Magnets to the Circuit.

It is a law of the electric circuit, that *the maximum magnetic force is developed when the resistance of the coils of the electro-magnets in circuit is equal to the resistance of the other parts of the circuit;* i. e., *the conducting wires and battery.*

An electro-magnet is of the best proportions when the total thickness of the coils, measured from the outside to the core, is equal to the diameter of the core. When, therefore, the coils must be of high resistance, they are wound with a great length of *fine* wire. When the resistance of the circuit is light, a shorter length of coarser wire is used.

PART II.—THE MORSE TELEGRAPH.

Fundamental Principle.

The Morse telegraph system is so called from the name of its inventor, Samuel F. B. Morse, an American, who constructed the first line between Baltimore and Washington in the year 1844.

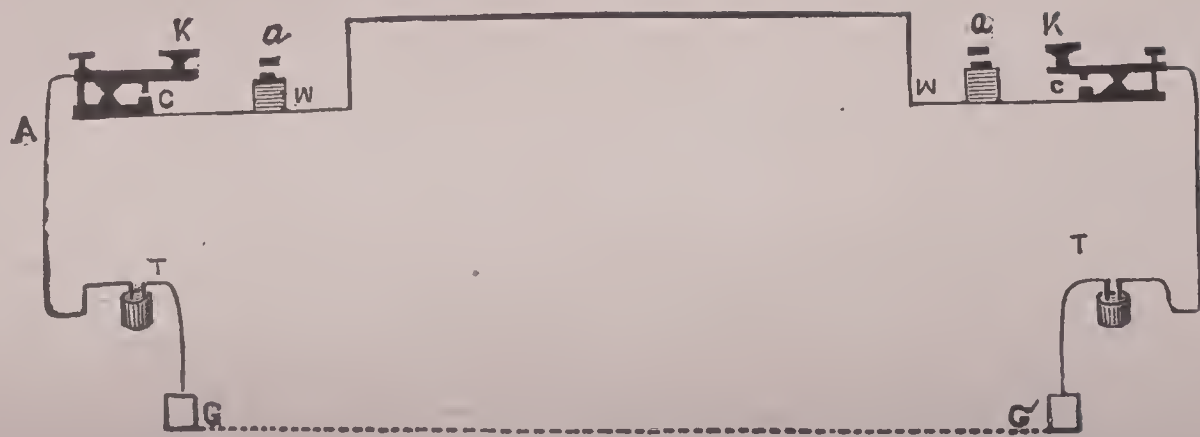
Morse's telegraph operates upon the principle, that an electro-magnet may be alternately magnetized and demagnetized by stopping and starting a current of electricity, by opening and closing the circuit of which the electro-magnet forms a part.

Telegraph Circuits.

Fig. 7 represents a telegraph circuit, consisting of a line wire stretching from the station A to the station B; a battery T, an electro-magnet M, and a key K, for opening and closing the circuit, at each of the stations. To avoid the expense of a second wire to complete the circuit between the two stations, the line wire, after passing through the magnet, key and battery at each end of the line, is run to the ground at G, completing the circuit through the earth. Besides being less expensive, this plan has the additional advantage that the resistance of the circuit completed through the earth is less than it would be through a return wire, as the resistance of the earth is practically nothing. On very short lines sometimes a second wire is used, which constitutes what is called a *metalic* circuit.

When the circuit is closed at A by means of the key, K, the current traverses the circuit, passing through both electro-magnets, M M. causing them to attract

Fig. 7.



Telegraph Circuit.

their armatures as long as the current continues. When the circuit is again opened by the key, the current is interrupted, and the electro-magnets release their armatures. The effect is the same whether the circuit is opened and closed by the key at A, or at B. The effect, also, upon the electro-magnet is the same whether the key is at the same station with the magnet, or at another station many miles distant.

By the original method of operating the telegraph, the armature of the magnet at each station was attached to one end of a lever having a sharp pointed steel style in the other end, which indented a strip of paper drawn before it by means of clockwork. If the armature was attracted but an instant, the style came in contact with the paper only an instant, and indented it with a short mark, or *dot*. If the armature was attracted for a longer time, the result was a longer mark, or *dash* upon the paper. Thus, it will be observed, dots and dashes may be marked upon the paper by closing the circuit by

the key for a shorter or a longer time. If different combinations of dots and dashes are used to represent letters, it is evident that a message may be transmitted by means of the key at one station to the electro-magnet at another.

In more recent practice, the method of marking the signs upon paper has been superseded by arranging the lever attached to the armature in such a way that it will give sounds at shorter or longer intervals according to the time the circuit is closed. These intervals between sounds may be considered as representing dots and dashes, and for convenience the terms dot and dash are retained.

Intermediate Offices.

An indefinite number of intermediate or way stations may be introduced in the circuit between the two terminal stations of the line, each station or office being provided with its key and magnet. The circuit may be opened by a key placed at one of these intermediate stations, at any point on the line, and the effect upon

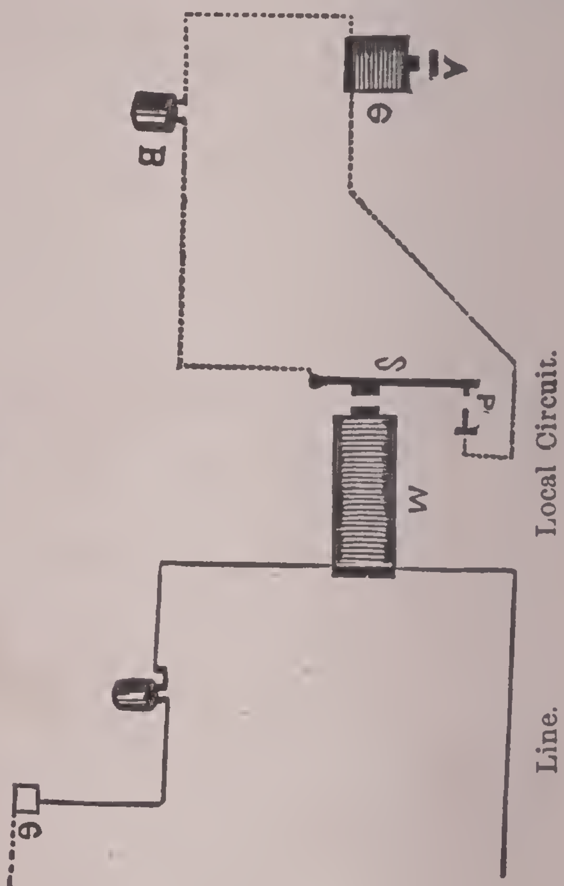
every magnet in the circuit will be precisely the same; but it is obvious that only one key can be operated for opening and closing the circuit at the same time.

The Local Circuit.

On a circuit as long as a telegraph line reaching from city to city, the resistance of the long line of wire is so great that the current is often weakened to such an extent in passing over it, that sufficient magnetic force is not developed in the electro-magnets to attract their armatures with the power necessary to mark paper, or give a satisfactory sound to the motions of a lever. For this reason, instead of placing the magnet of the recording or sounding instrument in the *main* circuit, its place is supplied by a *relay* magnet, M, (Fig. 8). The armature of the relay magnet is attached to a lever, S, which opens and closes the circuit of another battery, B, at the point P. This second or *local* circuit is represented by the dotted lines. When the *main* circuit, or line is closed, the relay magnet attracts its

armature and closes the *local* circuit, in which is placed the recording or sounder

Fig. 6



magnet G. The lever of the relay magnet is so light that a weak current is sufficient to work it, but the resistance of the local circuit, which is composed of only a few feet of wire, is so small that

nearly the entire force of the local battery is effective upon the local magnet. It will be noticed that although the local circuit depends for its action upon the main circuit, the main circuit is entirely separate and independent from the local, and is not affected in the least by its action.

Ground Wires.

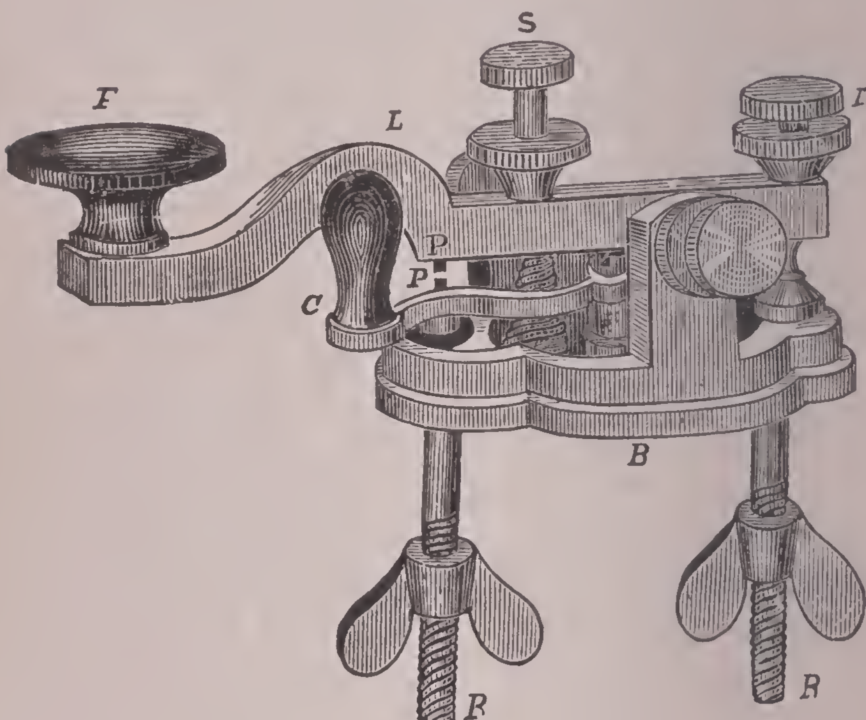
At every intermediate station, a wire called a *ground wire* is run from the office to the ground. This wire may be connected with the line wire so as to divide the main circuit into two distinct and independent circuits. The uses of the ground wire will be explained more fully hereafter.

The Key.

The key, or sending instrument is represented in Fig. 9. It consists of a lever of brass, L, about five inches long, which is hung on a shaft between two set screws on the frame or base B. The key is fastened to the operating table by two legs, R R′, which pass through the table and

are secured by nuts underneath. The circuit is formed through the key by cutting the wire of the main circuit and con-

Fig. 9.



Key.

necting one of the ends to each of the legs. The leg, R′, is in direct connection with the brass base of the instrument, but the other leg. R, is insulated from it by being set in a piece of hard rubber, so that the circuit is broken at this point and

the current cannot pass from R′ to R. The leg, R, terminates in a *platinum point*, P, and a similar platinum point, P, is placed in the lever L.

When it is desired to complete the circuit, the lever is pressed down by the pressure of the fingers upon a hard rubber finger piece, F, bringing the two platinum points, P P, in contact, and completing the connection between R′ and R through the lever and platinum points. When the pressure upon F is released, a spring under the lever restores it to its former position, separating the platinum points, and the circuit is broken.

C is a *circuit closer*, which completes the connection and closes the circuit permanently when it is pushed against the anvil which forms the top of the leg, R. This is always done when the key is not in use, for if the circuit through it was not completed in this way, the current could not flow through the circuit, and all the other keys situated in it would be useless. The play of the lever, or the

distance between the platinum points is regulated by a set screw, D, in the end of the lever. Sometimes another set screw, S, is provided for regulating the tension of the spring under the lever.

The Relay.

The Relay consists, as shown in Fig. 10, of a large intensity electro-magnet, supported by a frame of brass on a dry hard wood base. The armature of the electro-magnet is attached to a lever, which plays between two adjustable set screws, fixed in the frame of the instrument. As this lever acts as a key to open and close the local circuit, it is provided with a platinum point which strikes upon another platinum point on the end of the set screw. The platinum point of the lever is in electrical connection, by means of wires beneath the base of the instrument, with one of the binding posts, and the point in the screw, with the other. The wires of the local circuit are connected to these

binding posts. The coils of the magnet are in connection with the binding posts

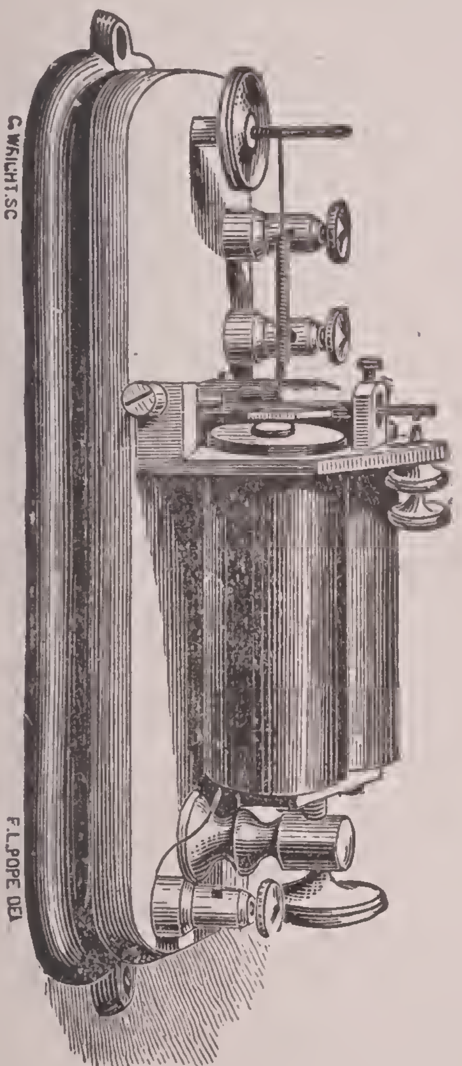


Fig. [illegible] Relay.

behind the coils, to which the main line wires are attached, and the magnet put

in circuit. The tension of the spring which draws the armature and its lever back, and opens the local circuit when it is not closed by the attraction of the magnet, is regulated by an adjustment. The distance of the magnet from the armature is regulated by another adjustment, called the "back adjustment."

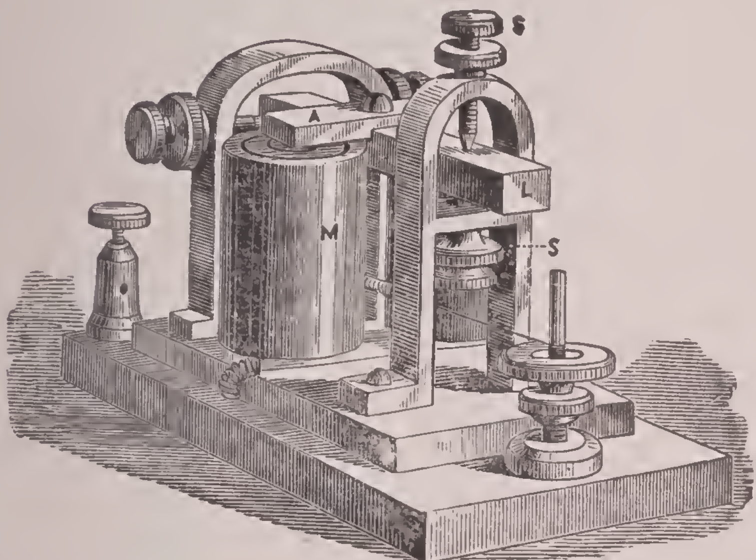
The coils of relay magnets are wound with very fine wire, usually No. 30 to No. 36, and with a resistance varying to suit the resistance of the circuit. The coils of electro-magnets used in telegraphy are generally covered with hard rubber, as a protection to the wire.

The Sounder.

The *Sounder*, or receiving instrument is shown in Fig. 11. It consists simply of a small electro-magnet, having a resistance of from 2 to 4 ohms; an armature and heavy sounding lever, which plays between two adjustable set-screws; and the necessary frame-work of brass, mounted upon a base of wood. An adjustment is provided for regulating the tension of the spring of the armature. The

magnet is put in circuit by means of two binding posts on the base of the instrument.

Fig. 11.

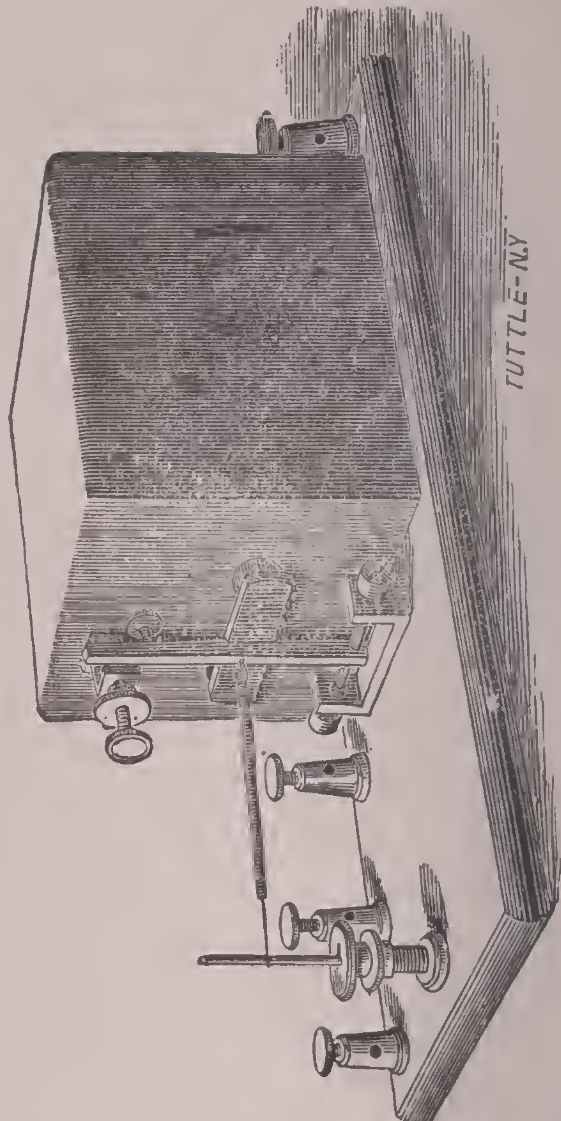


The Sounder.

Main Line Sounders.

When the current of the main circuit is sufficiently strong, the local circuit and sounder is sometimes dispensed with, and the relay is converted into a sounder by giving its lever more "play," or motion, and thereby increasing its sound. More frequently a *Main Line Sounder* is used. This instrument is made in a variety of forms, and numerous devices have been

Fig. 12.



Box Relay.

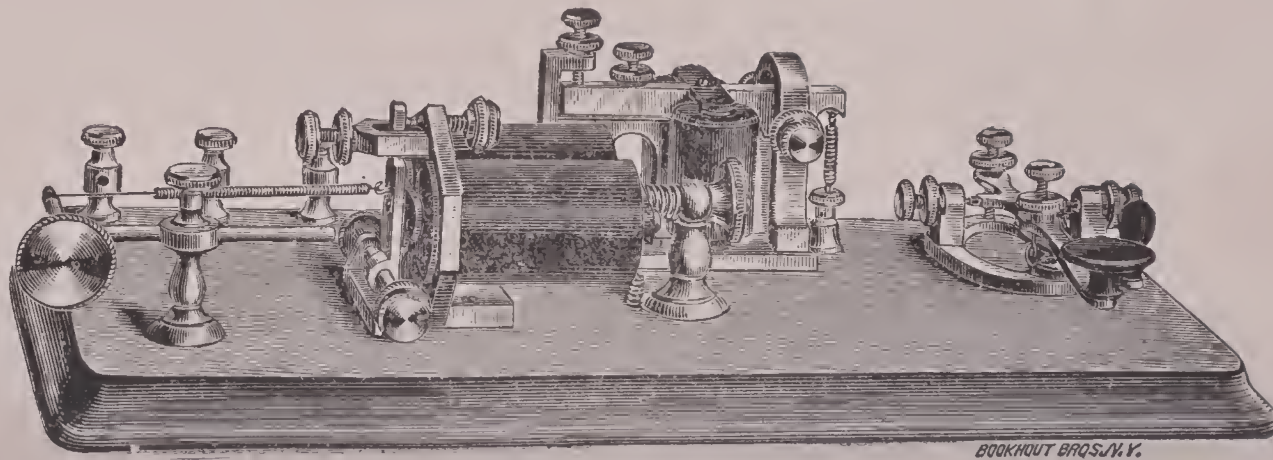
employed to increase the sound of the lever, which must often be operated by a comparatively weak main line current.

The Box Relay.

The instrument called the *Box Relay* is so arranged that it may be used advantageously either as a relay or as a main line sounder. The magnet coils are inclosed in a small wooden box against which the lever strikes (Fig. 12), thus increasing the sound. These instruments, when made with a key upon the same base, are convenient portable instruments for opening temporary offices.

Note.—The form of key now in general use has a lever of steel made in a single piece with the trunnion shaft. Fig. 13 is a combination set, showing such a key, with relay and sounder, of the most modern pattern, on one base. These instruments, either in combination or separately, the quadruplex machinery, switches, etc., as well as the galvanometer and rheostat shown in Part I, are illustrations of apparatus manufactured by J. H. Bunnell & Co., 76 Cortlandt Street, New York.

Fig. 13



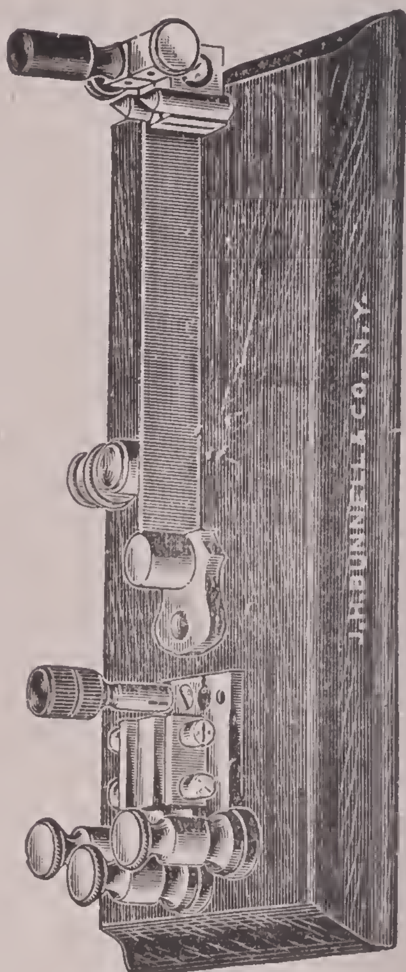
Morse Combination Set.

Cut-Outs and Other Switches.

When an office is left with no one in charge the wires should be "cut out," or disconnected from the line. The cut-out is made in various simple forms, usually combined with a ground switch, and sometimes with a lightning arrester. The form called the *plug switch* (Fig. 14) has been extensively used. A plug is made of two pieces of brass separated and insulated from each other by a piece of hard rubber. The instruments of the office are connected with the two sides of this plug by flexible conducting wires. When the office is to be put in circuit, or "cut in," the plug is inserted between a pin and a brass spring, as shown in the figure. The main line wires are attached to the binding posts at the top of the switch, one of which is in connection with the pin, and the other with the brass spring. It is obvious that as the two sides of the plug are insulated from each other the current must pass through the office; but when the plug is with-

drawn the brass spring presses against the pin, closing the main circuit, and

Fig. 14.



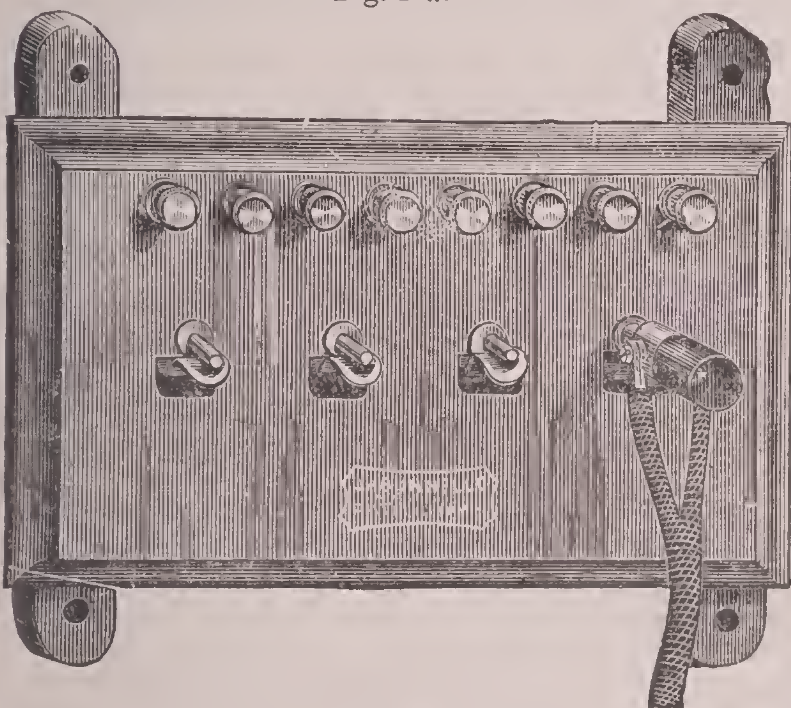
Plug Switch.

leaving the office entirely disconnected, or "cut out." The switch shown has

ground switch and lightning arrester at the top.

A later form, called a *spring cut-out,* is shown by Fig. 14*a*. The plug is cylindrical, and the operation of the cut-

Fig. 14*a*.



Spring Cut-Out.

out device is obvious. The figure shows cut-outs for four wires. They are usually made for from one to three lines in connection with ground connectors and lightning arresters, and may be used

wherever it is not required to make cross connections of wires, or any changes other than changing instruments from one line to another. Other forms of switches are used, and for various purposes, but they are too numerous to be described within the limits of this little book.

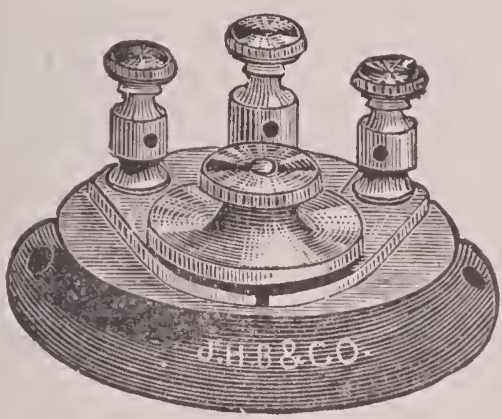
Lightning Arresters.

The fine wire coils of the relay magnet are sometimes burned or injured by atmospheric electricity, which follows the wires into the office during the prevalence of electric storms. As a protection, *lightning arresters* are sometimes used. Both the line and ground wires are attached to the lightning arrester, so that a charge of atmospheric electricity entering the office by the line wires is carried to the ground. The lightning arrester is made in several forms, but the principle involved is much the same in all of them: that is, that atmospheric electricity, being of high intensity, will leap a slight break in the conductor, or overcome con-

siderable resistance in order to force its way to the ground; while the galvanic current, being of lower intensity, is unable to overcome such resistance and is confined to the line.

A common form, the *disc arrester,* is shown in Fig. 15. A disc of brass is

Fig. 15.

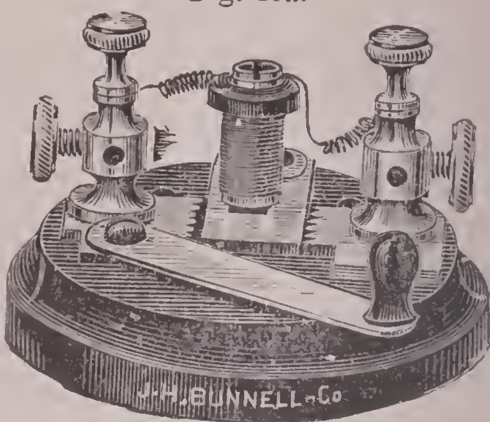


Disc Arrester.

screwed over brass plates connecting with line and ground, but not quite touching them. Another form is arranged with pointed screws projecting from the line-wire plates toward the ground-wire plate, leaving a very small space between the plate and the points, over which the lightning leaps, making its way to the

ground. (See Fig. 14.) Other forms have notches or "saw teeth" projecting from one plate in proximity to another. The *plate arrester* does not vary materially in principle from the disc arrester. In the *quadruplex arrester* (Fig. 15*a*) a very fine coil of wire is fused by the lightning, thus making connection with the ground plate. It is commonly used with quadruplex apparatus as a protection to the finely wound magnets of the relays.

Fig. 15*a*.



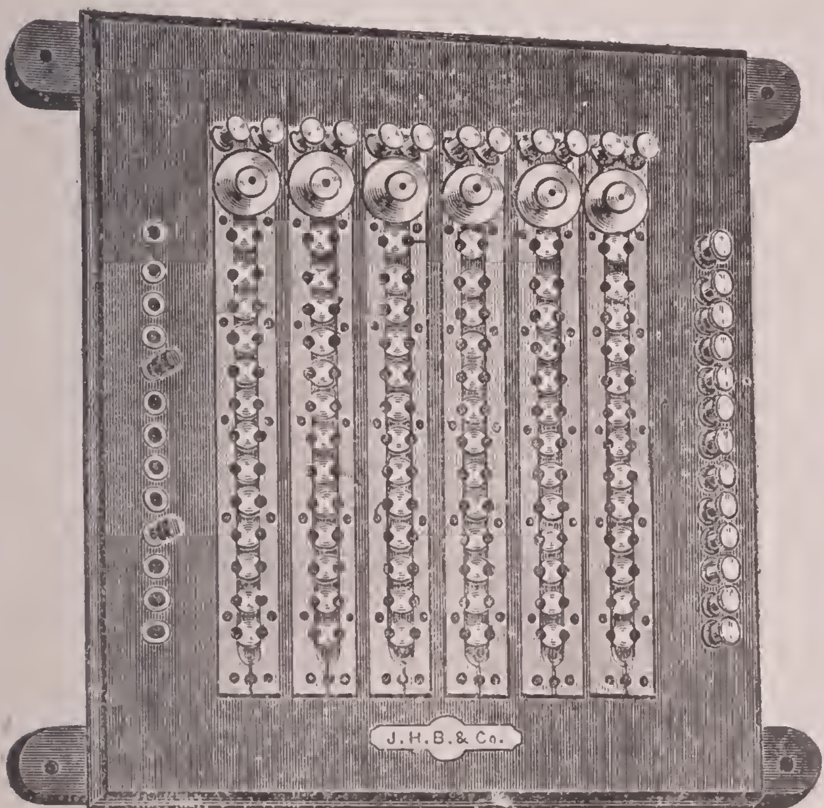
Quadruplex Arrester.

THE SWITCH BOARD.

A *switch board* is generally used in offices having two or more wires entering them. The form now in common use is

shown in Fig. 16. The connections of brass are arranged upon a board of dry hard wood, as represented, and fitted

Fig. 16.



Switch Board.

with binding posts at the top, to which the line wires are connected. Other straps of brass pass horizontally across

the back of the board, and are in connection with the binding posts at the side of the board, to which the instrument wires are connected. Each of these back straps is in connection with one of the horizontal rows of studs which appear between the line straps upon the face of the board. By inserting plugs in the holes between the studs and line straps connection is made with the instrument straps. It is clear that any instrument may now be connected with any line wire, and a little study of the connections will show that any two line wires may be cross connected, or that any desired wire east from the office may be connected to any other wire west, or any required changes in the wire connections be made. The lowest row of studs is connected with the ground wire. By inserting a plug at the bottom of the board, connecting the east and west line straps together, the wire is cut out. The board shown is provided with disc lightning arresters.

Large switch boards are often fitted with *spring jacks* for cutting in the instruments, the straps being then used only for cross connections, battery connection, etc., thus rendering a much fewer number of horizontal connectors necessary. Otherwise, the board would often be of an inconvenient or impracticable height if horizontal connections were required for every instrument.

The spring jack consists essentially of a plate or strap of brass upon which the jack, also of brass, is held firmly by means of a spring. Each of these is in connection with one of the ordinary board straps to which the two ends of the line wire are connected, and which are thus effectually cut out. The instrument wires are connected through a flexible conducting cord, similar to that used with the ordinary plug switch, with the two brass sides of a wedge which are separated and insulated from each other by hard rubber. When this wedge is inserted between the jack and the lower plate the instrument is cut in.

Loops.

What is technically termed a "loop" in telegraphy, is a wire branching off from the main circuit, running to some point and returning again to the line. A loop is arranged so that it may be cut out from the line if necessary. A plug switch is the most convenient for this purpose, the switch being put in circuit at the office where the loop commences, and the wires of the loop attached to the plug.

Arrangement of Offices.

In the arrangement of offices, the line wire entering the office first passes through the cut-out switch and lightning arrester, and then through the key and the magnet of the relay. It is immaterial which of these latter instruments is first in order in the circuit, as long as they are all properly connected. The circuit, after passing through the apparatus, is made complete to the ground, if it is a terminal office; or runs back through the lightning

arrester and cut-out, out of the office and on toward the next station, if it is a way station. The connections of the local circuit, which is entirely confined to the office, may be understood by reference to Fig. 8.

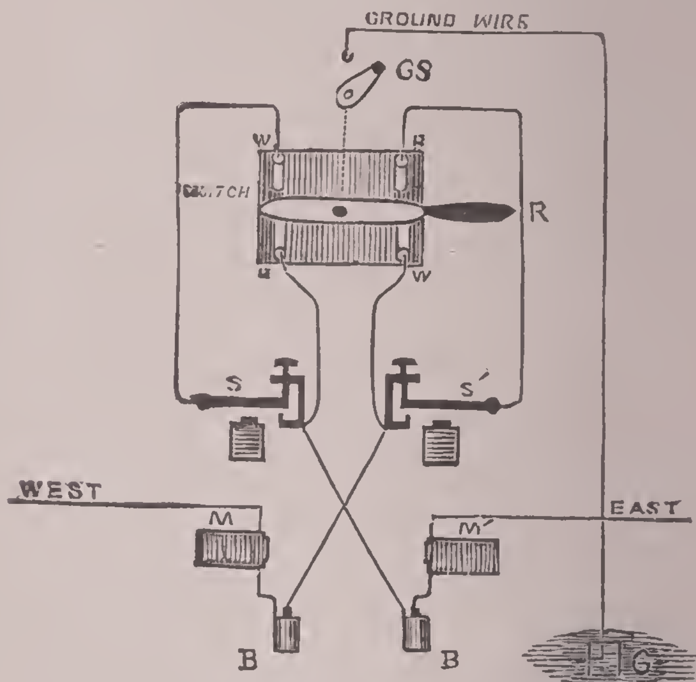
Arrangement of Batteries.

Two batteries are generally used on the main circuit, one at each end. The number of cells in each battery is equal under ordinary circumstances, and the number will depend upon the length and resistance of the circuit. Not only should the different cups of each battery be connected with regard to the law of attraction and repulsion, but the batteries at each end of the line should be placed with *opposite poles to the line*, in accordance with the same law. Frequently, several wires are worked from the same battery on the principle of a "divided circuit"; and in this case it is important that the wires should equal each other in resistance as nearly as possible.

REPEATERS.

When the length of a telegraph circuit renders it of too great resistance to be worked satisfactorily, the circuit is divided into two or more parts, and a *repeater* is

Fig. 17.



Repeater.

used. The repeater "repeats," or transmits the signals received on one circuit into the other, much in the same way as the relay repeats the signals from the main into the local circuit. The re-

peater must be arranged so as to transmit from *either* circuit into the other, according to the direction in which the message may be going.

The connections of a simple "switch repeater" are shown in Fig. 17. M and M′ are the relay magnets of the eastern and western circuits respectively; and S and S′ are the sounders of the eastern and western circuits; B and B the main-line batteries. The local circuits connect the sounders with the relays in the ordinary manner, but the local wires are omitted in the figure, in order to avoid confusion of the lines.

The sounders, S S′, are of a peculiar construction, their levers being provided with platinum points, similar to those of a relay. The opposite main circuit passes through the lever and platinum points of each sounder, so that, as the sounder is worked by its relay, it repeats the signals through its platinum points into the opposite circuit.

With the switch, R, in the position shown in the figure, the two circuits

work through, not as a repeater, but as a single circuit. This may be seen by tracing the connections in the figure. It should be remembered that the wires *do not touch each other* at points where they are represented as *crossing* each other. By connecting the ground wire by means of the ground switch, GS, the through circuit is divided into two distinct and independent circuits.

When the apparatus is arranged as a repeater, the ground wire is also connected. When the switch, R, is turned so as to connect the points W and W, the western sounder, S, repeats into the eastern circuit. When the switch, R, is turned so as to connect the points E and E, the reverse operation takes place, and the eastern sounder, S′, repeats into the western circuit. The operation may be readily understood by carefully tracing the connections with the lever, R, in the several different positions named.

It will be noticed that the switch must be turned every time the sending changes from one circuit to the other. Several

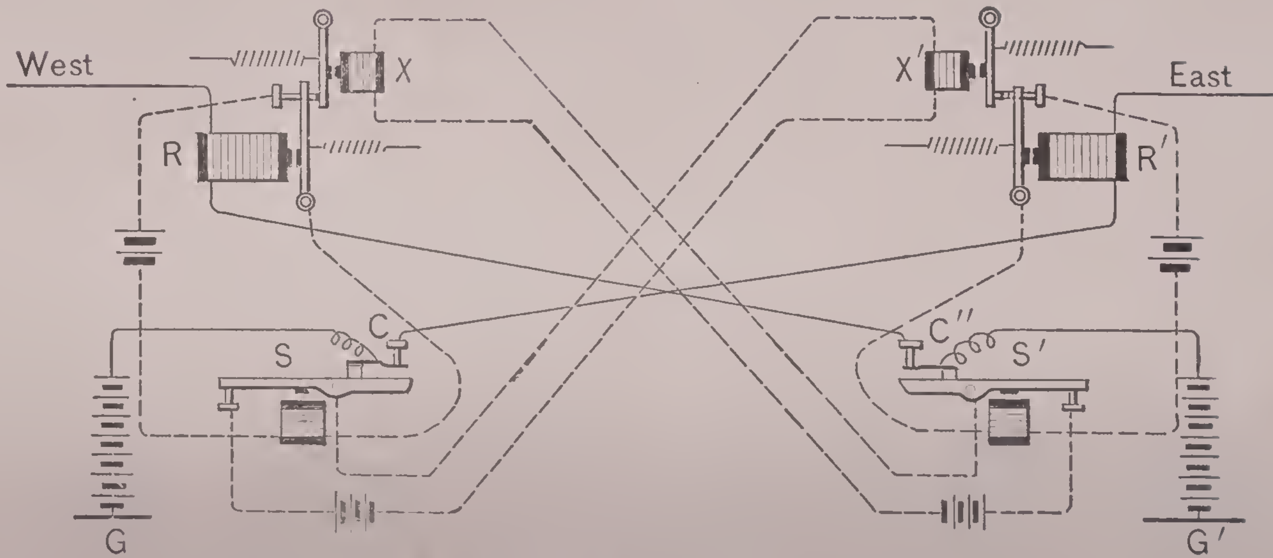
forms of "automatic repeaters" are in use, in which this result is automatic, the only attention necessary being in keeping the apparatus properly adjusted.

Automatic Repeaters.

Of the various forms of automatic repeaters, the Milliken-Hicks repeater has been adopted by the Western Union Telegraph Company as their standard. The principle of its operation may be understood by reference to the diagram, Fig. 18. The relay is shown in Fig. 18*a*.

Each circuit passes through the larger magnet of the relay, and repeating points of the repeating sounder, to ground. The local circuit connects contact points of relay with the sounder magnet in the usual manner. An extra local circuit runs through the extra magnet, X, of the relay and the extra contact points of the sounder on the opposite side. Now, let the west circuit open key. Relay R opens, and through its local circuit opens sounder S, which opens the east circuit

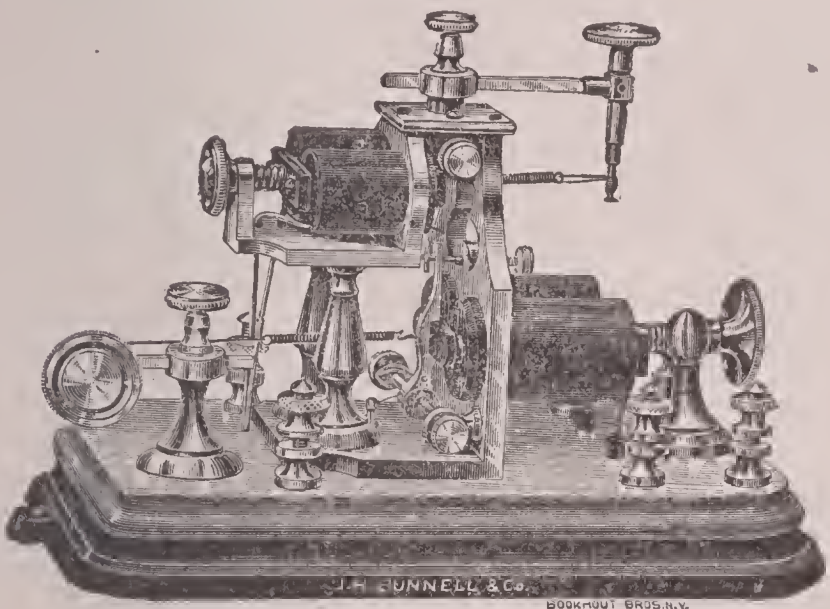
Fig. 18.



Milliken-Hicks Repeater.

at *C*. But S at the same time opens the extra local circuit of the extra relay magnet X′, and its armature lever falls back and is drawn by the retractile spring firmly against the lever of R′, thus pre-

Fig: 18*a*.



Milliken-Hicks Relay.

venting the breaking of the east local circuit, and holding the repeating sounder on that side closed. The east circuit repeats into the west in the same manner. The keys, not shown in the diagram, are connected in the usual manner.

PART III.—THE QUADRUPLEX.

Duplex and Quadruplex Systems.

A *duplex* telegraph is a system whereby a single line wire is utilized for the simultaneous transmission of two messages—as usually understood, one in each direction.

A *quadruplex* telegraph is a system whereby a single line wire is utilized for the simultaneous transmission of four messages—two in each direction.

Experiments in duplex transmission were made in England, Austria, and Germany as early as the year 1853, but nothing of practical value seems to have been accomplished until 1868, when J. B. Stearns of Boston introduced his duplex system upon the lines of the Franklin Telegraph Company. It was not until 1872 that improvements were made by the same inventor which rendered his system practicable upon long lines. The quadruplex was invented by T. A. Edison in 1874, and important

improvements were made later by various American electricians.

The polar duplex is still in use, and an examination of the principles involved in both that and the Stearns system will be necessary as preliminary to the study of the quadruplex.

The Stearns Duplex.

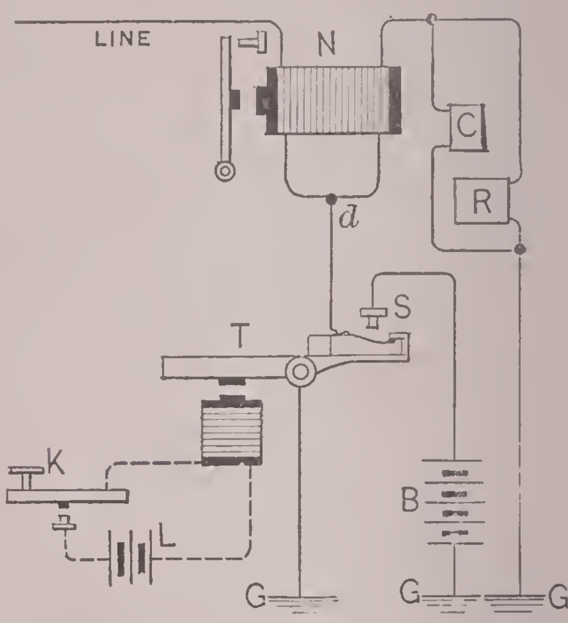
In studying any system of double transmission, consider that it is only essential that each relay shall respond freely to the signals transmitted from the distant station, without interference from those transmitted at its own station, by which it remains entirely unaffected.

Reference is first made to principles stated in Part I.: When a current divides between two branches of a circuit, equal currents will traverse branches of equal resistance. When currents of equal strength pass in opposite directions through the coils of an electro-magnet, no magnetic effect is manifested.

The principle of the Stearns duplex may be readily understood by reference

to Fig. 19, which shows connections at one end of the line, station A, only, the connections at station B being identical. N is a differentially wound or neutral relay, T a single-current transmitter, R

Fig. 19.

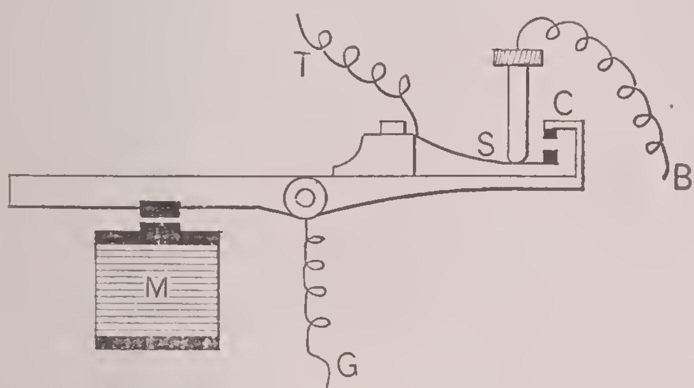


Stearns Duplex.

a rheostat, and B the battery. The key, K, is not located in the main circuit, but operates the transmitter through a local battery and connections, L, the transmitter itself performing the service of opening and closing the main circuit.

The transmitter lever and connections are shown on a larger scale by Fig. 19*a*, G representing the ground connection, T the line, and B the battery connection. The position shown is when key is closed and magnet M attracts its armature. The opposite end of the lever is now

Fig. 19*a*.



Transmitter Connections.

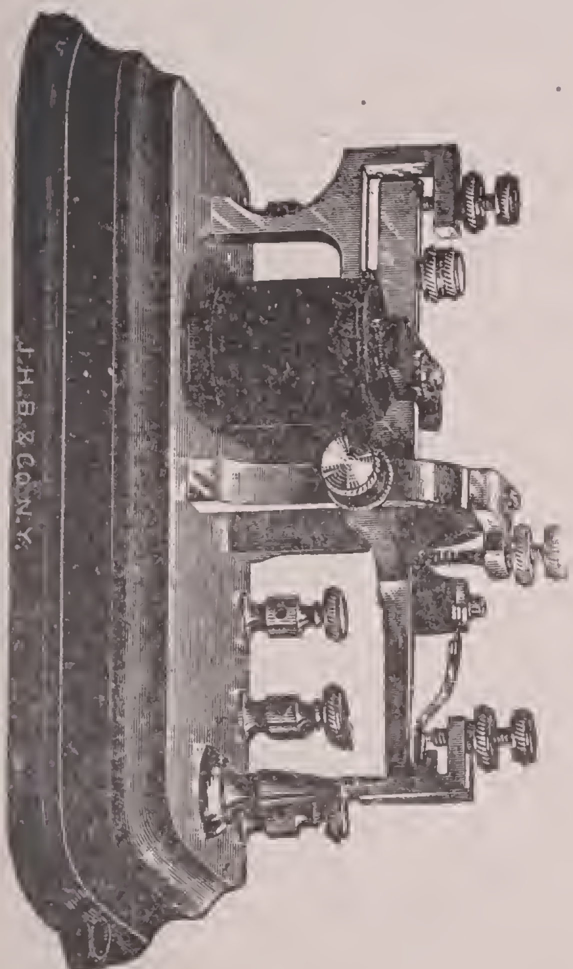
elevated, and the spring, S, which is insulated from the lever, is brought into contact with the set-screw, making connection from battery to line. When key is open the same end of the lever moves downward, breaking contact with B, and spring S presses upward, making contact with C, establishing connection between

ground and line. Thus, when the key is closed battery is to line, when it is open line is to ground.

The current from T divides at *d* (Fig. 19), passing in opposite directions through the coils of the neutral relay, one branch through the rheostat circuit to ground, the other to line. The resistance of the rheostat being adjusted to make these currents of equal strength, no magnetic effect is produced in the relay. That portion of the current going to line, however, passes through the line coil only of the relay at the distant station, B, and this current not being balanced by any current through the second coil, the armature of relay at B is attracted in response to signals from A, while the armature of relay at A remains inert.

Now, let key be closed at station B, and a similar effect is produced, but in the opposite direction, relay B remaining unaffected while relay A responds. These effects are produced during simultaneous transmission from both ends of the line, whether the keys are closed simulta-

neously or not. If A closes key at the same instant with B, the neutral effect is produced in both relays by the current



Transmitter.

Fig. 19b.

from the home battery, but each receives an additional strength of current from the distant station through the line coil of its relay which moves the arma-

ture. Thus, under all conditions, each relay is unaffected by signals sent at its own station, while it responds to those from the distant station.

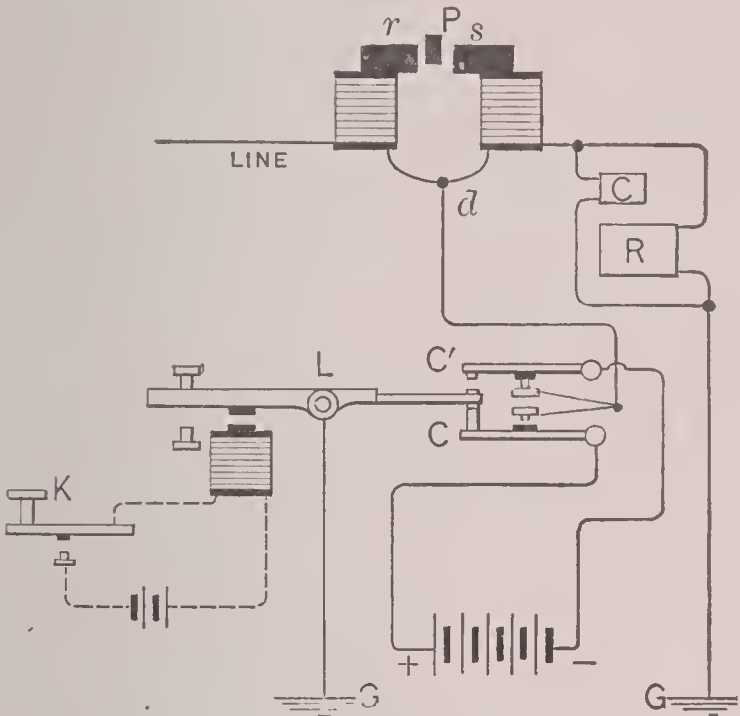
The neutral relay is similar in appearance to the ordinary Morse relay, and operates a sounder through a local battery and connections, not shown in the diagram. The transmitter is shown in Fig. 19*b*.

THE CONDENSER.

A line wire will, to a certain extent, induce electricity in other objects, especially adjacent wires upon the same route, and thus, acting as an electrical condenser, will take up an additional charge. In the duplex, when the transmitter suddenly cuts off the battery and substitutes a route of small resistance to the ground, a portion of this accumulated charge will return to the ground rather than overcome the greater resistance of the line. This return charge is known among operators as the "kick." The result is a momentary magnetization of the relay, which causes a false movement of the

armature. To counteract this a condenser is used, which may be adjusted to counteract the accumulative capacity of the line, and which, discharging itself through

Fig: 20.



Polar Duplex.

the magnet coils in an opposite direction, may neutralize the effect of the kick.

The condenser, as usually constructed, consists of sheets of tin-foil separated by alternate sheets of mica, enclosed in a

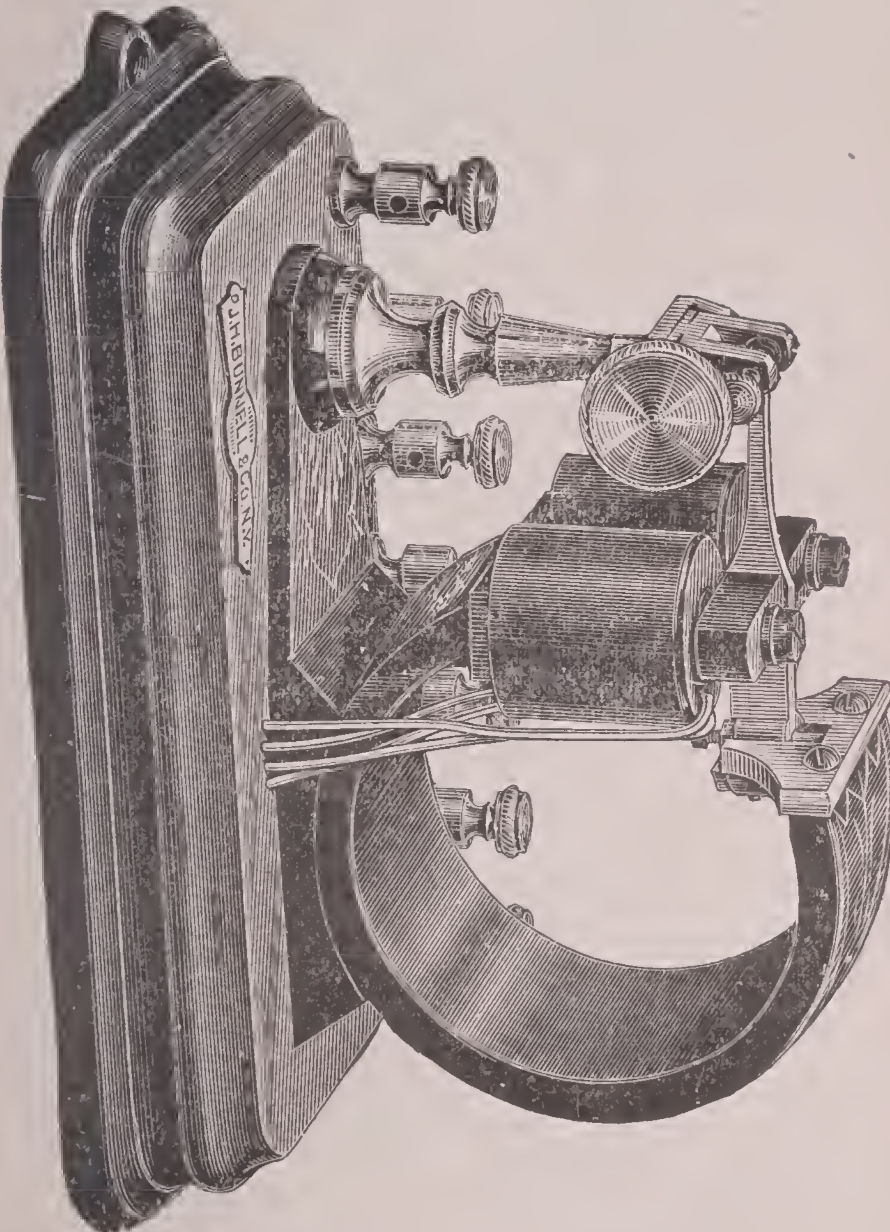
flat wooden box. Alternate sheets of tin-foil are connected to line and ground in groups, and any number of groups required may be placed in circuit by means of plugs. C is the condenser in Figs. 19 and 20.

The Polar Duplex.

The polar relay is shown in Fig. 20*a*. A large permanent magnet of a curved form is mounted upon a base. The electro-magnet cores are differentially wound and fastened to the south pole of the permanent magnet, and so become south poles by induction. The armature lever is connected with the north pole of the permanent magnet, and so its end, projecting between the cores, becomes a north pole by induction. Now, as long as no current passes, both cores are, at their upper ends, south poles, and the lever is attracted equally by them, as long as it is adjusted midway between them, and remains inert.

The *pole-changer* (Fig. 20*b*) is the instrument by means of which the direction of the current is changed, thus producing

Fig. 20*a*.



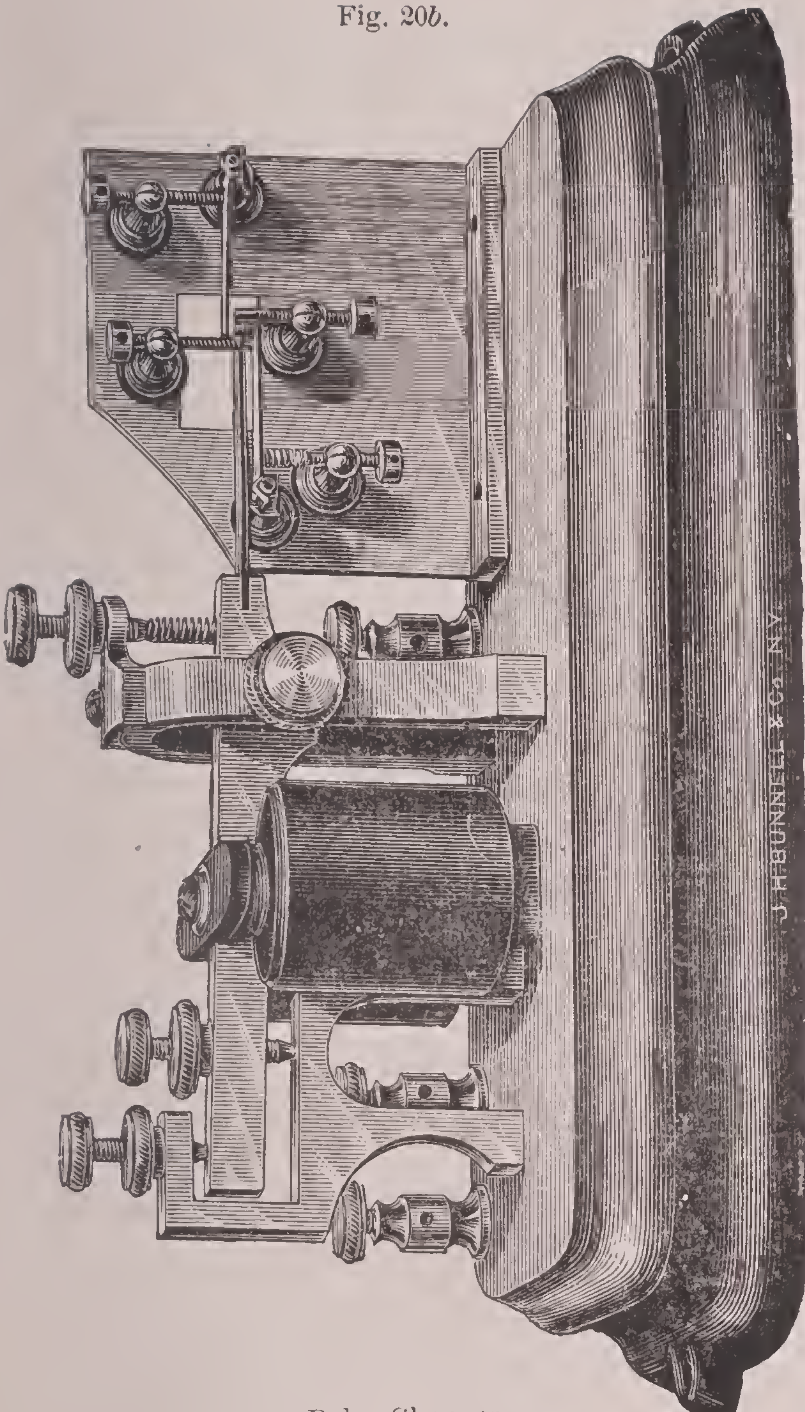
Polar Relay.

changes of polarity in the relay. It is operated by a key and local battery.

Fig. 20 is a theoretical diagram of the polar duplex, and shows the operation of the pole-changing device. A thin strip of metal projects from the end of the armature lever, L, which is at all times in connection with the ground. The position shown is when key is open, the armature end of the lever being elevated, while the contact end is depressed, which places the + pole of battery to ground through contact spring c, while the — pole is to line through c'. When key is closed the contact end of lever is elevated, lifting c' from the set-screw below it, and allowing c to come in contact with the set-screw above it, placing + pole to line and — pole to ground.

P is the polar relay, and currents from either C or C' divide at d, one branch through one coil of the relay to line, the other through the second coil of relay and the rheostat, R, to ground. As in the Stearns duplex, the rheostat is balanced to line, and the two branch currents are

Fig. 20b.



Polar Changer.

of equal strength, and passing through the coils in opposite directions, produce no magnetic effect.

Now, suppose the strength of each branch of the current traversing the coils at station A to be represented by 3, and that while the + pole of battery at A is to line we place the — pole of battery to line at the distant station B. Then there will be an additional current having a strength of 3, from battery at B, passing through the line coil at A, and its armature is attracted to *s*. In like manner, at B the — current from its battery will be augmented by a + strength of 3 from the battery at A through the line coil at B, and its armature also attracted to *s*.

Now, the first requirement is that each relay shall remain unaffected by changes or polarity of its home battery. Open the pole-changer at A, reversing the poles from + to — to line. Station B still has — pole to line, and the two batteries being now opposed to each other, no current passes through the line coil of relay

at A, but there is still a current flowing in through the second coil, and in the same direction as before the change of polarity, and this repels the armature, which remains as before.

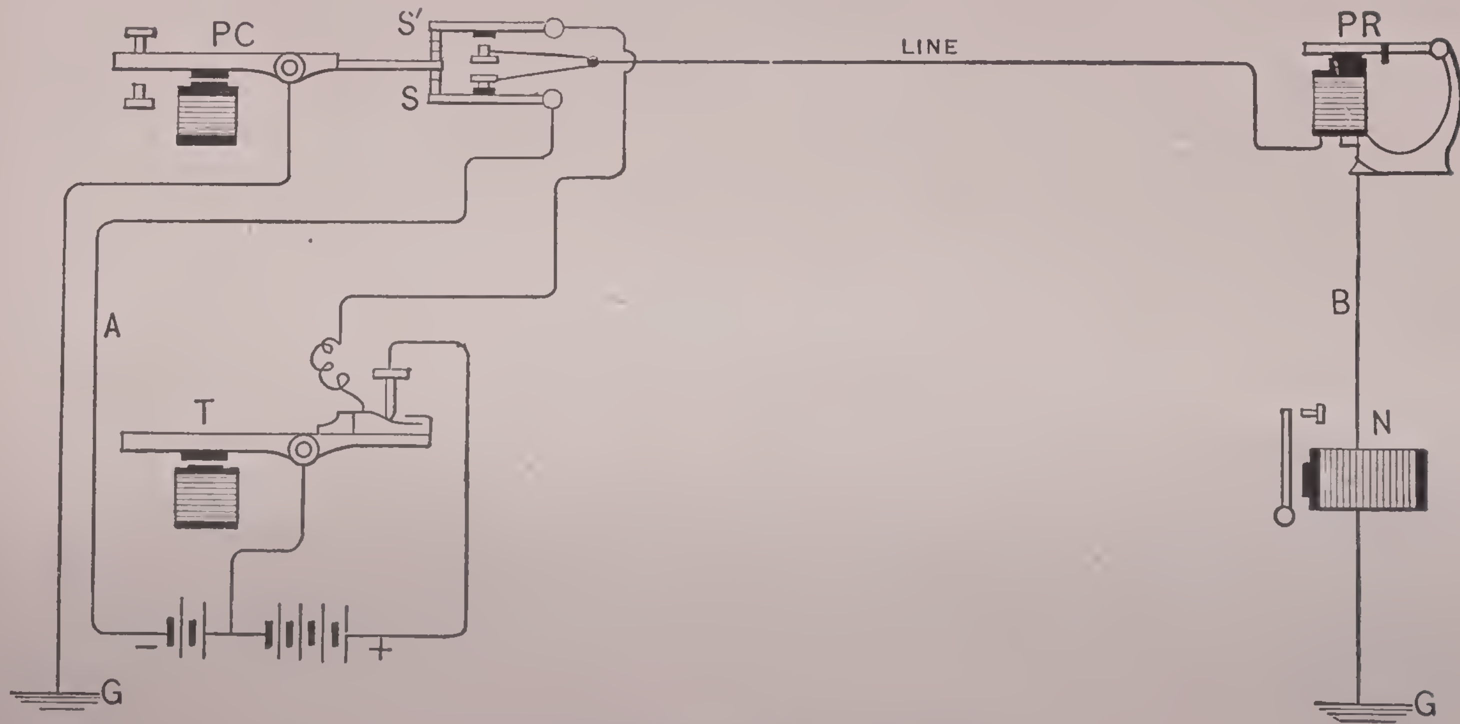
The second requirement is that the armature of either relay shall respond to changes of polarity at the distant station. Let A have + pole to line and let distant station B change from — to +. The two batteries now oppose each other and no current passes through the line coil at A, but a current of 3 still passes through the rheostat branch to ground through the second coil and in a direction opposite to that before the change of polarity at B. Therefore the armature is repelled to *n*. As these effects occur in either direction, each relay responds only to changes of polarity at the distant station.

The use of condenser C is to give a static discharge and prevent the "kick" at the instant of changes of polarity.

THE QUADRUPLEX.

These two systems of double transmission combined, with certain modifica-

Fig. 20c.

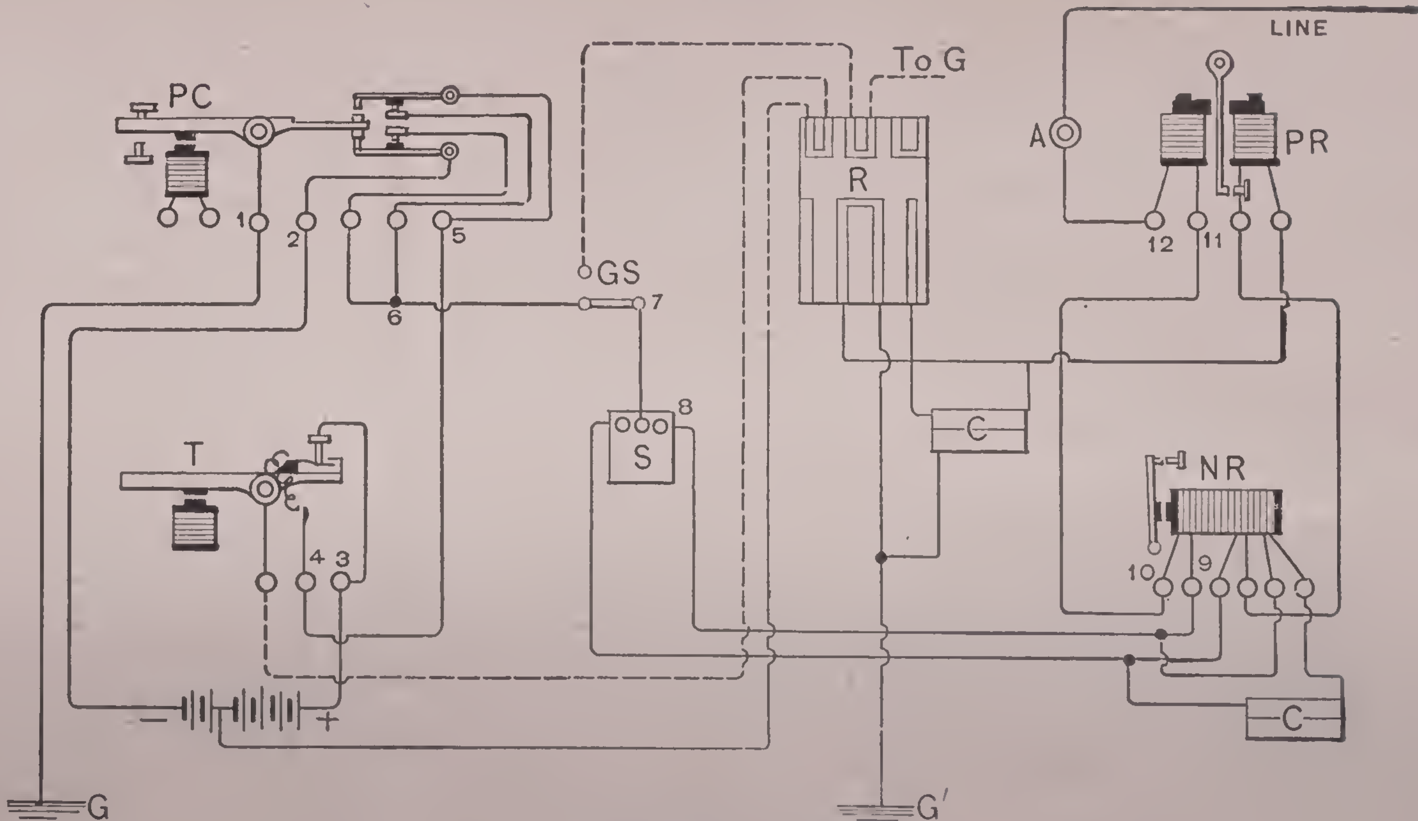


Double Transmission in One Direction.

tions, form the quadruplex. The most important modification relates to the Stearns system. In this duplex, which operates on the primary conditions of battery to line and no battery to line, there will be intervals when there is no current on the line from either battery. Again, the polar system operates upon the principle of changes of polarity, and it is evident that when combined with the Stearns duplex the interruption of the current by the Stearns side will interfere with the working of the polar side. This difficulty is overcome in the quadruplex by arranging the battery in two sections, and the transmitter, instead of cutting off battery entirely when the key is open, leaves one third of it in circuit, while the entire battery is in circuit when the key is closed.

Simplify the explanation by reference to Fig. 20*c*, which is a theoretical diagram showing the combination of the neutral and polar principles to work in one direction only, the two sending instru-

Fig. 20*d*



Quadruplex Connections.

ments being at station A and the two receiving instruments at station B. The circuit, starting from ground at G, passes to the pole-changer, PC, thence from contact s to $-$ pole of battery, from $+$ pole of battery to contact of transmitter T, thence to the other contact s' of PC. A *tap wire*, cutting off two thirds of the battery called the *long end*, connects with lever T as a substitute for the ground connection of the Stearns duplex.

At station B, the polar relay, PR, responds only to changes of polarity, or direction of current, without regard to strength. The neutral relay, N, responds only to increase in strength of current without regard to polarity. Thus, PR responds only to PC, and N responds only to T. The polar relay, therefore, intended to respond to changes of polarity in currents of varying strength, is made very sensitive, the coils being usually wound to about 400 ohms resistance in each direction. The neutral relay is less sensitive, being wound to about 200 ohms in each direction, and its retractile spring

is adjusted to such a tension as to resist the attraction of the armature when the transmitter at station A is open, and it receives the strength of only one third of the battery (the *short end*), while it responds when the transmitter is closed and it receives the strength of the whole battery. Thus, the continuity of the circuit is never broken by either T, or PC at station A. T varies the strength of current going to station B, while PC changes its polarity although the signals transmitted by PC may vary in *strength* according to the position of T at the particular instant, and it is evident that each relay at B will respond independently.

The diagram, Fig. 20*d*, shows the actual connections of the quadruplex at one station. The circuits connecting transmitter T, pole-changer PC, and the line coils of neutral relay NR and polar relay PR, and thence to line, are represented by unbroken lines. The branch circuit through the second coils of the relays and rheostat to ground are shown in broken lines. Other connections are in fine dotted lines. The local circuits oper-

ating the transmitter, pole-changer, and sounders, are omitted from the diagram.

Trace the line connections, which run virtually the same as in Fig. 20*c*, from the ground, G, following the figures on the diagram to 6, where the connections with the two back stops of PC unite, thence to ground switch, GS, and resistance box, S. Here the circuit divides for the two coils of the relays, the unbroken lines passing through the first coil of the relays, and lightning arrester, A, to line; the broken lines through the secondary coils, and rheostat, R, to ground at G′. The battery tap wire is shown in fine dotted lines, and it will be noticed that instead of running directly to the transmitter lever, it makes a loop through a small set of resistance coils which are included in the same box with the rheostat. This resistance is adjusted to balance the internal resistance of the long end of the battery, which is cut off by the transmitter when the circuit is through the tap wire, and thus prevent variations of resistance in the circuit resulting from the division of the battery.

At each change of polarity of the battery, the line wire, on long circuits, may accumulate a static charge, producing a kick in the polar relay, and a condenser is used, as shown, to neutralize this effect. At the instant of change of polarity, the armature of the neutral relay also has a tendency to fall back, thus mutilating the signals on the neutral side. This defect is remedied by placing the contact point of the neutral relay on the back stop, and a repeating sounder is substituted for the ordinary local sounder. The repeating sounder again reverses the signals, which are then received on a sounder through an extra local circuit. Now, the time of demagnetization of the neutral relay, during the changes of polarity, is so short that the armature is again attracted before it makes *firm* contact on the back stop, hence the armature of the repeating sounder does not move sufficiently to mutilate the signals as received on the sounder.

The polar side is also called the *No. 1 Side*, and the neutral side the *No. 2 Side.*

PART IV.—PRACTICAL TELEGRAPHY.

Alphabet and Numerals.

The Morse, or dot and dash alphabet is as follows:

A	. —	J	— . — .	S	. . .
B	— . . .	K	— . —	T	—
C	. . .	L	——	U	. . —
D	— . .	M	— —	V	. . . —
E	.	N	— .	W	. — —
F	. — .	O	. .	X	. — . .
G	— — .	P	. . . . .	Y	. . . .
H	. . . .	Q	. . — .	Z	. . . .
I	. .	R	. . .	&	. . . .

Period	. . — — . .
Comma	. — . —
Exclamation	— — — .
Interrogation	— . . — .

The following are the punctuation marks:

1	. — — .	6	. . . . . .
2	. . — . .	7	— — . .
3	. . . — .	8	— . . . .
4	. . . . —	9	— . . —
5	— — —	0	———

Several other characters formerly used for punctuation have become obsolete, and combinations of letters are used instead, as "Pn" for *parenthesis*, "Qn" for *quotation*, etc. The combination "Sx" is also used for the dollar sign ($).

Adjustment of Instruments.

The proper adjustment of the instruments is always an important duty, and often a difficult one. Under ordinary circumstances, an armature should be adjusted so that there will be about space enough between it and the poles of the magnet, to insert a piece of heavy writing paper, when the armature is attracted toward the magnet. If the armature *touches* the poles of the magnet it will "stick."

In stormy weather, which renders the insulation of the line defective, the magnet of the relay must be drawn back, by means of the adjustment screw, to a greater distance from its armature. The reason of this is, that the escape of the current from the line causes *residual* magnetism in the cores of the relay magnet, which must be counteracted by adjusting back the cores. The spring of the relay armature must be adjusted to suit the strength of the current. In stormy weather adjusting is often exceedingly difficult, and it is sometimes almost impossible to keep the relay working. In

such cases the key should not be opened until the relay is carefully adjusted, to make sure that no other office is using the circuit.

When the key "sticks," or fails to break circuit, it is usually caused either by the platinum points becoming burned and roughened by the passage of the current, or by dirt and dust around the anvil and platinum points, which forms a partial connection when the circuit is opened. The platinum points may be cleaned by a piece of heavy writing paper, or fine emery paper, or, in an extreme case by a very fine file; but much filing of the points should be avoided.

When the relay works properly and the sounder does not work, the fault is in the local circuit. The cause will generally be found in a broken or disconnected wire, or in weakness of the local battery. All the connections and binding posts in an office, especially those of the main circuit, should be carefully watched, and kept closely and firmly screwed up. The lightning arresters should be kept clean,

and always carefully examined after an electric storm.

Testing Telegraph Lines.

The interruptions which occur in the working of telegraph lines are most commonly caused by *breaks*, *escapes*, or *crosses*. Trouble is also sometimes caused by a loose joint or connection in the circuit, or by the escape of the current from one wire to another on the same poles when they are imperfectly insulated, or by a defective ground wire connection.

Breaks.

The most common causes of the breaking of the circuit are a key left open, or a broken line wire. When a break occurs the relays will all remain "open," and the result is a total suspension of business upon the circuit. Every operator should proceed to test for the break by connecting the ground wire of his office, first on one side of the instruments and then on the other. Supposing the break to be east of an office, no "circuit" is made

when the ground wire is put on west of the instruments, but when it is put on east of them the circuit of the battery at the

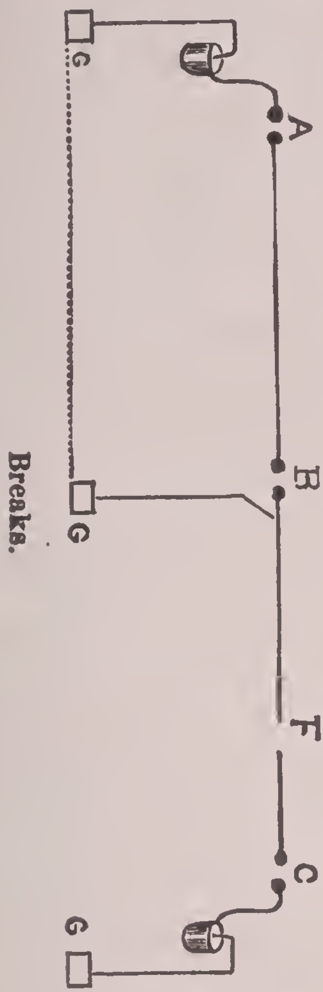


Fig. 21.

west end of the line is completed through the ground wire, and all offices west of the ground wire can work with each other.

This is made clearer by reference to Fig. 21, which represents a line with three offices, A B C, with a break at F, between B and C. When the ground wire at B is put on west of the office the break interrupts the circuit, but when it is put on east the circuit is complete between A and B, showing that the break is east of B. In this way, it is evident that the fault may be located between some two stations.

Escapes.

Escapes often occur, in a greater or less degree, all along a line, from defective insulation, especially during stormy weather. When, however, there is an escape at any particular point, it may be located as follows: The circuit manager should call up the offices in order, beginning with the one at the farther end of the line, and have them open circuit for a moment. When the circuit is open beyond the escape a little current will still pass over the line, completing its circuit through the escape and ground.

On the line shown in Fig. 22 the escape is at F. When the key at C is open there will still be a current at A, which

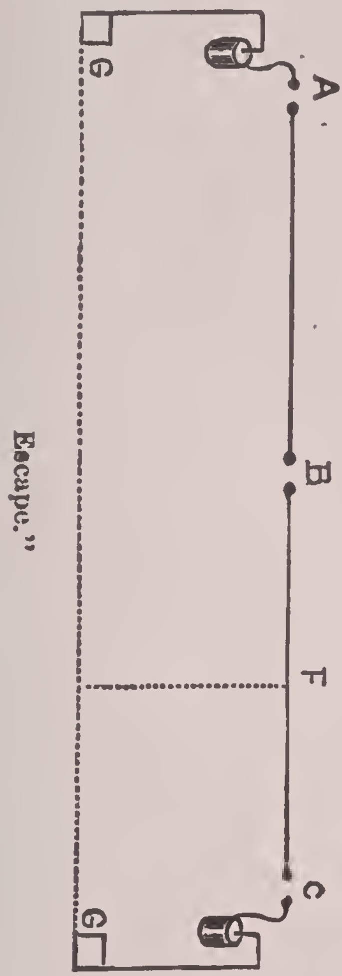


Fig. 22.

passes through the escape and ground. When the key at B is open this current is stopped, locating the escape between B and C.

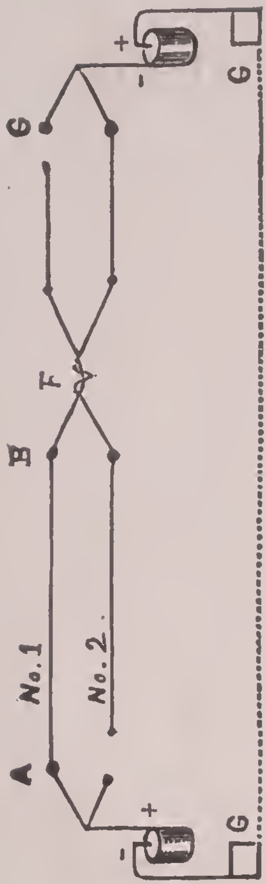
Grounds.

The only difference between an escape and a ground is, that a ground causes the loss of the whole, and an escape of only a part of the current. A ground is tested for and located in the same way as an escape. A ground is often caused by a ground wire being carelessly left on in an office.

Crosses.

Fig. 23 represents a line with two wires, No. 1 and No. 2, which are crossed between B and C. To locate the cross the circuit manager at A should open No. 2 as shown, and have C open No. 1 and send dots on No. 2. These dots will be transferred at the cross from No. 2 to No. 1 and come on No. 1 at A. If, however, B opens No. 1 and attempts to send dots on No. 2, there is no circuit on either wire, as they are both open, one at A and the other at B, showing that the cross is beyond B.

Fig. 23.



Cross.

MAINTENANCE OF BATTERY.

To start the battery, place the parts in position, put from $\frac{1}{2}$ to $\frac{3}{4}$ of a pound of sulphate of copper (blue vitriol) in the bottom of the jar, and fill it with water sufficient to cover the top of the zinc.

The battery should be allowed to stand quietly, so as to avoid mixing the solutions, and when newly set up, must stand for several hours on closed circuit before it will develop its normal electro-motive force. Sulphate of copper is composed of oxide of copper and sulphuric acid. It is decomposed by the action of the battery, the copper being separated from the acid and deposited upon the copper plate of the battery in the form of a scaly crust, while the acid attacks the zinc, by which it is constantly consumed, forming sulphate of zinc in the upper part of the jar. The battery, if in proper condition, should show a distinctly marked line of separation of the solutions, although, as usually cared for, it seldom does so. As the sulphate of copper is constantly being dissolved, a few crystals may be dropped to the bottom of the jar once in every two or three days, keeping the blue line of separation up to within about one inch of the bottom of the zinc. On the other hand, the zinc solution is constantly increasing in density, and a little may be

drawn off from time to time by means of a syringe, and replaced by fresh water. The zinc should be removed from the jar occasionally and cleaned with a brush. The battery should be kept clean, and not allowed to freeze, for when frozen the current is weakened or altogether suspended.

Balancing the Quadruplex.

The ground switch, GS, in Fig. 20*d*, is used in making the balance of the quadruplex. The distant station is requested to "ground." This cuts out his whole battery and pole-changer, but includes a resistance in the rheostát box, as shown in the diagram, which is equal to the internal resistance of the battery, consequently the balance will be correct when the battery is again cut in. Now, the station making the balance turns his switch to ground also, and line is without battery at either end. Adjust the armature of polar relay so it will remain on whichever side it is placed. Then cut

in full battery and adjust the rheostat until the armature of polar relay will again remain on whichever side it is placed, showing that the resistances of the line and rheostat branches are equal. Finally, opén and close the pole-changer and adjust the condenser until the polar relay does not respond to the static charge or discharge of the line.

The polar duplex is balanced in a similar manner.

PART V.—CONSTRUCTION OF LINES.

THE improper and imperfect construction of telegraph lines is often the cause of much unnecessary trouble and waste of material in working them. It is proposed to give, in this chapter, a general idea of the proper construction of a line, with such hints as may be of assistance to students and amateurs in the construction and equipment of private and short lines.

The essential parts of a telegraph line are the conductors, which form a path

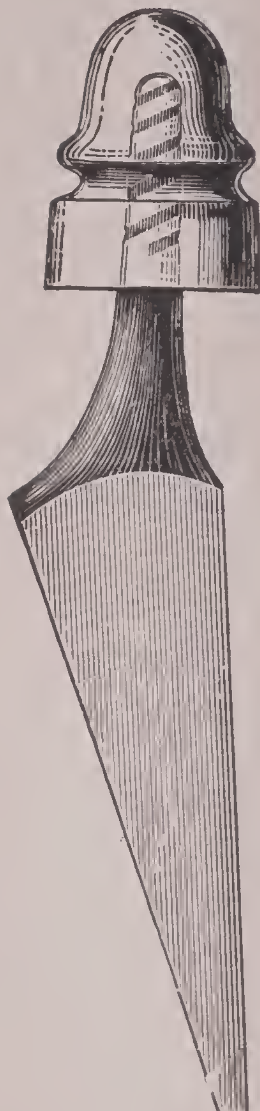
for the current, and the insulators, which confine the current to the conductors and prevent its escape to the ground. The poles are not essential to the working of a line, but serve merely as a support for the conductors, which are insulated from them at each point of support.

The Conductors.

Galvanized iron is most commonly used for line wire, as plain iron wire is liable to rust, which impairs its conducting power. On the best lines the sizes known as Nos. 8 and 9 are generally used, but a smaller size, as No. 11 or No. 12, will answer for short lines. It should be remembered that the smaller the size of the wire the less is its conducting power, and consequently, the greater the battery power that will be required to work it.

Great care should be exercised in making joints or splices, either in the line or office wires. One loose joint often gives more resistance than a great length of continuous wire. The proper way to make a joint is to twist the end of each

Fig. 24.



Glass Insulator.

wire several times closely around the other, with the several turns of wire at right angles to the line. Wires should never be *hooked* together and bent back upon themselves.

Line wires of hard drawn copper are now in common use, especially for quadruplex and important circuits.

The Insulators.

The glass insulator, shown in Fig. 24, is the most common form. It is made to screw upon a thread cut upon a bracket which is spiked to the side of the pole, or, more frequently, upon a pin which is set in a cross-arm. The line wire is fastened to the insulator by a short piece of wire called *tie wire*, which is passed around a groove in the insulator and its ends twisted around the line wire on each side. The insulator should never be fastened to the bracket by a spike driven over it into the pole, nor should the edge of the insulator be allowed to touch the top edge of the bracket or the side of the

pole, for this forms a connection between the insulator and the pole, causing an escape when the insulator is wet.

Various other forms of insulators are used for ordinary line work, or for special purposes.

Fitting up Offices.

The line wires usually pass into an office directly over a window, and are carried through insulating *window tubes* of hard rubber. An enlarged head is usually made on the end of the tube which is inside the office. The line wire is securely fastened to an insulator outside the office whence it runs through the tube. The end of the wire which projects through the tube is commonly bent into a hook, and the copper office wire spliced to it. A large number of close convolutions should be made around the line wire, and the joint carefully soldered. A better method is to cut a thread upon the end of the line wire, upon which a binding post may be screwed to receive the office wire.

Wires are now frequently brought into offices by using insulated copper wires grouped in cables, which are connected to the line wires within a box fixed to the pole outside the office. A lightning arrester is generally used in connection, the ground wire running down the side of the pole.

Copper wire is used within offices. No. 16 is the most common size, and it is usually insulated by a covering of cotton or linen. It may be fastened to the walls or table whenever desired by small wire staples. The arrangement of the apparatus and batteries has already been explained. Splices in office wires should be very carefully and firmly made.

Ground-wire Connections.

Ground wires should be insulated with gutta-percha, or some other material not liable to be affected by exposure to the weather, and firmly attached to a large plate of metal, buried deep enough in the ground to be beyond the reach of frost, and always in connection with moist earth. For a short line a sheet of cop-

per or tin having a surface of several square feet will make a good ground connection. The ground wire should be soldered to the plate, so as to insure a firm contact.

Private and Short Lines.

A short line may be operated much more economically and satisfactorily by the observance of the proper proportions between the conductors, instruments, and batteries. The rule of the "Proportion of Electro-magnets to the Circuit" has been given in Part I. As it is not often convenient to measure the resistance of short private lines, the approximate resistance per mile of galvanized iron line wires is given below. If the line is well constructed, these figures will approximate to the resistance of the line, under favorable circumstances.

No. 8	wire,	about	16	Ohms	per mile.
No. 9	"	"	20	"	"
No. 10	"	"	24	"	"
No. 11	"	"	30	"	"
No. 12	"	"	36½	"	"

For an example, suppose a line one and one-half miles in length, of No. 10 wire. Its resistance by the above figures would be 36 ohms. The resistance of the electro-magnets should, according to our rule, equal that of the line. If there are four magnets in circuit they should have a resistance of 9 ohms each, as 36÷4=9. This gives a resistance of the whole circuit as follows:

Resistance of Conductor....	36 Ohms.
" " 4 Magnets, 9 ohms each..	36 "
Total.........	72 Ohms.

The internal resistance of a battery sufficient to work a line of so light a resistance is so small that it need not be taken into account. Under favorable conditions, 4 cells of Daniell, Hill or Callaud battery will operate this line satisfactorily.

The comparative strength of current with different numbers of cells of battery may be calculated by Ohm s Law, given

in Part 1, thus ;—the electro-motive force of a cell of battery being taken at 56 :—

With 2 cells of battery, electro-motive force is 112, resistance of circuit is 72—$112 \div 72 = 1.55$ effective strength of current.

With 4 cells of battery, electro-motive force is 224, resistance of circuit is 72—$224 \div 72 = 3.11$ effective strength of current.

The resistance of the whole number of electro-magnets should be equal to the resistance of the rest of the circuit, and the resistance of the magnets should be equal *with respect to each other.* Much more satisfactory results can be obtained in the working of a short line by having the magnets made to order of the resistance required. In most cases relays will not be necessary on such a line, but the common local sounders, of a high resistance, may be worked direct by the main line current.

In actual practice better results may be obtained by making the resistance of electro-magnets somewhat less than that

of the other parts of the circuit, making allowance for the defective insulation of the line, as on poorly insulated lines the actual resistance will be considerably reduced during wet weather.

In calculating the resistance of the short lines above considered, the internal resistance of the batteries is not taken into account. In actual practice this should always be considered, and the computation may be made by the following formula :

E.	equals the	electro-motive force of batteries.
R.	"	resistance of the line.
M.	"	resistance of the magnets.
B.	"	internal resistance of batteries.
C	"	strength of the current.

$$\text{Then } C = \frac{E}{R+M+B}$$

APPENDIX.

SUGGESTIONS AND EXERCISES FOR LEARNERS.

It is extremely desirable that a student of telegraphy should commence his practice under the instruction of a competent and thorough operator, but as many students are unable. at first, to obtain such instruction, the following suggestions may be beneficial to them, until they have an opportunity for practice in a regular telegraph office.

An erroneous idea prevails among many learners that it is an easy matter to learn to "send," and that it is proficiency in "receiving," or "reading by sound," only, which is secured by long and diligent practice. The style of sending of different operators varies as much as the style of penmanship of different individuals. If a student learns to send too fast

he will certainly acquire a bad style. A good rule is, never to let the speed of sending exceed the rate at which the same student has learned to receive by sound.

The first part of a student's education is the memorizing of the Morse alphabet, which has been given in another part of this book. When the characters have been learned, they may be practiced upon the key; but, as it is the opinion of experienced instructors that it is better not to practice the alphabet in its regular order, the letters are given hereafter in groups, each one of which forms an exercise which should be practiced until thoroughly mastered before commencing the next.

Attention should be given from the first, to the correct position of the hand in manipulating the key. Place the hand with the first two fingers upon the top of the finger piece of the key, with the thumb at the side, and partly beneath the finger piece. The third and fourth fingers should assume much the same

position as when holding a pen in writing The arm should rest upon the table at or near the elbow, with the wrist entirely free from the table. Keep the fingers constantly upon the key during manipulation, grasping the key firmly, but not too hard.

The force imparted to the key should be from the wrist, and not from the fingers, the wrist always moving in the same direction with the lever of the key. The pressure should be directly downwards, and not sideways. Let the motion be moderately firm, and give the lever the full vertical motion, so that the downward motion insures a firm contact between the platinum points, and the upward motion the complete breaking of the circuit.

The dots and dashes composing each character are separated from each other by *breaks*, the different characters are separated from each other by *spaces*, and words are separated from each other by a still longer *space*. Correct sending depends upon the perfect proportion in the

length of *dots* and *dashes*, ***breaks*** **and** *spaces*.

Practice the following exercises in order. *Do not leave one until it is thoroughly mastered.*

Exercise 1.

E.	I.	S.	H.	P.
.	..	...	....	.....

Make the breaks between the dots as short as possible, but let the upward motion of the key be full and free.

Exercise 2.

T.	L.	M.
—	——	— —

The dash should be three times the length of a dot. Make the dashes in M of equal length and close together. Do not make T too long, or L too short. L should be twice the length of T.

Exercise 3.

A.	U.	V.
. —	.. —	... —

Exercise 4.

N.	D.	B.
— ·	— · ·	— · · ·

Care should be taken to make the letters in the above two exercises compact, and to preserve the proper proportions between dots and dashes.

In the foregoing exercises there are four classes of letters, as follows :

First, dots.

Second, dashes.

Third, dots followed by dashes.

Fourth, dashes followed by dots.

The rest of the exercises include all the remaining letters of the alphabet, which are combinations of those already given.

Exercise 5.

F.	X.	W.	G.
· — ·	· — · ·	· — —	— — ·

Q.	K.	J.
· · — ·	— · —	— · — ·

The following are called the "spaced

letters," the "space" being just long enough to distinguish it from a "break."

Exercise 6.

O.	R.	&
. .	. ..	. ...
C.	Z.	Y.
.. .	... .	.. ..

The figures and punctuation marks are omitted in the above exercises, as they are more difficult than the letters, and it is better to practice the easier combinations until a complete control is gained over the key. When once the student has become master of the key he will have no difficulty in forming any character, and the figures and punctuation marks may be practiced in order, as given in another part of this book.

Fractions are formed by using a dot to represent the line between numerator and denominator.

In sending large numbers, a space, equal to that used between words, is used

to divide them into periods of three figures each.

After having learned thoroughly all the Morse characters, commence to practice short words, writing slowly and spacing carefully.

Particular care should be exercised in writing words containing spaced letters. The following words present a few examples, which will illustrate the difficulty of writing words containing a number of spaced letters: Ice, Erie, Rice, Cicero, Receive.

No forms for commercial and railroad messages are here given, as these are among the details of telegraph business, with which the student should familiarize himself by actual practice in a regular telegraph office.

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